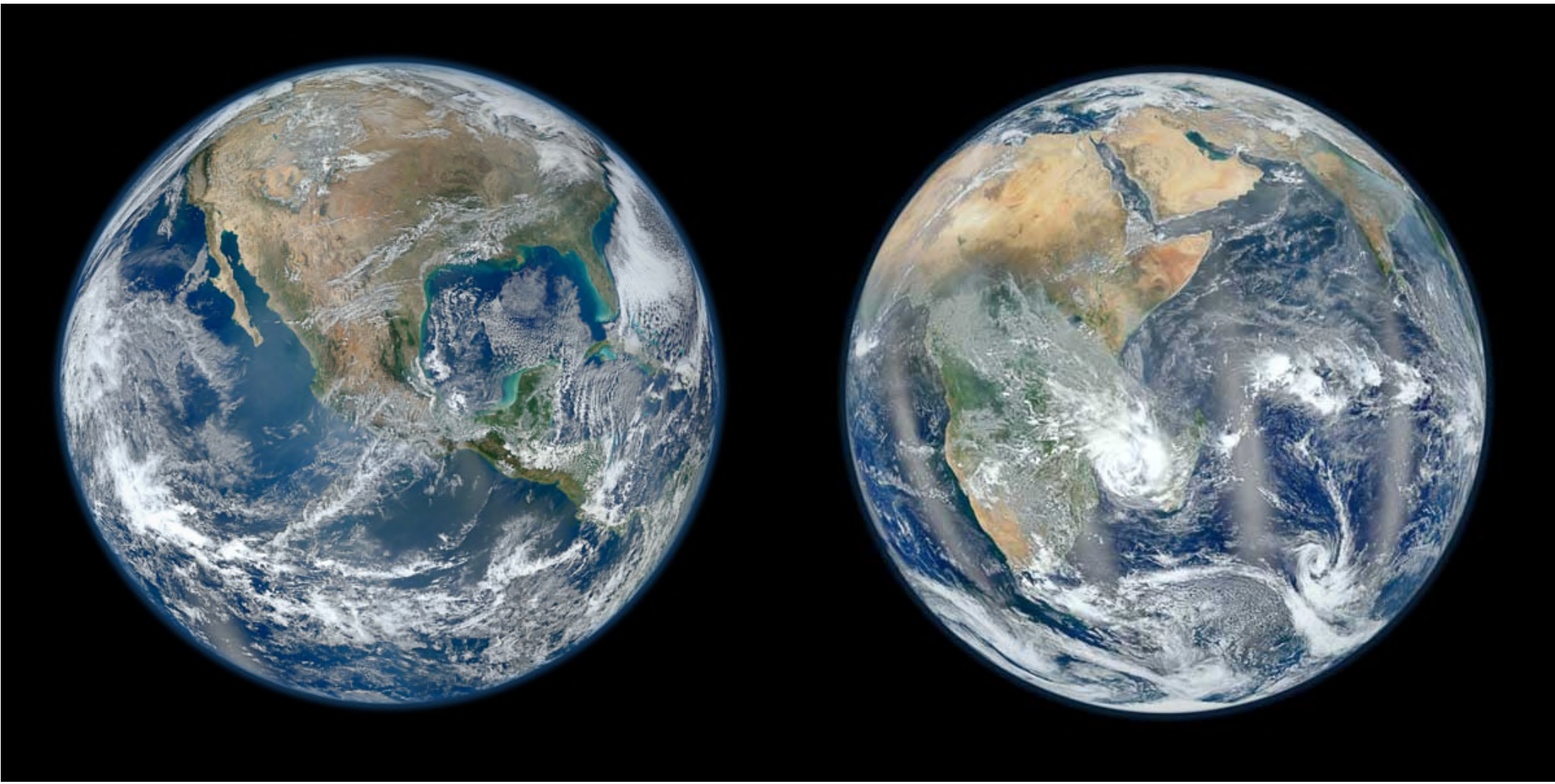
Use of In-Situ and Airborne Multiangle Data to Assess MODIS, VIIRS, and Landsat-based Estimates of Directional Reflectance And Albedo



Miguel O. Román, Charles K. Gatebe, Crystal B. Schaaf,
Edward J. Masuoka, and Robert E. Wolfe

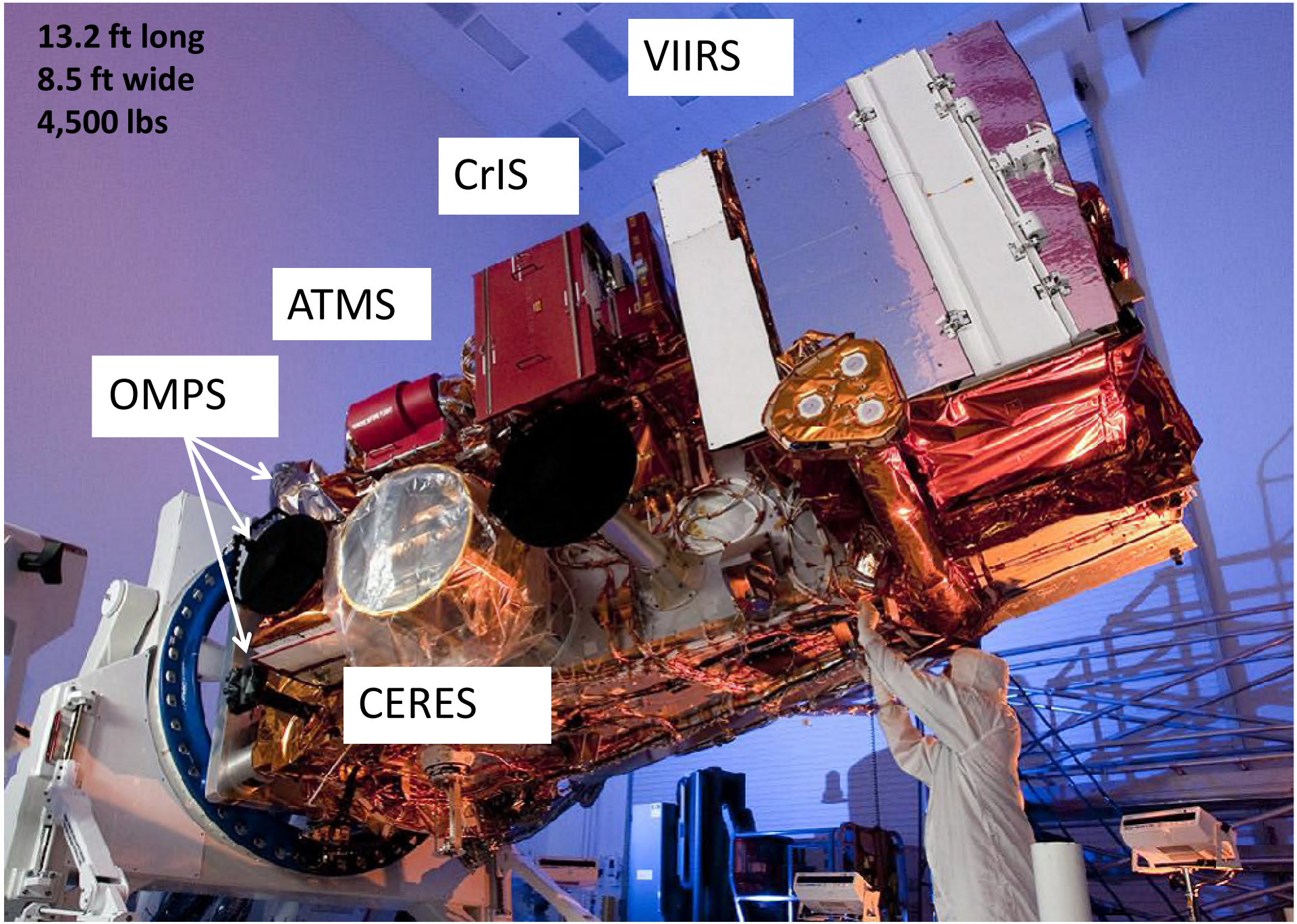
Twelfth BSRN Scientific Review and Workshop
AWI, Postdam, Germany, August 1-3, 2012

Overview

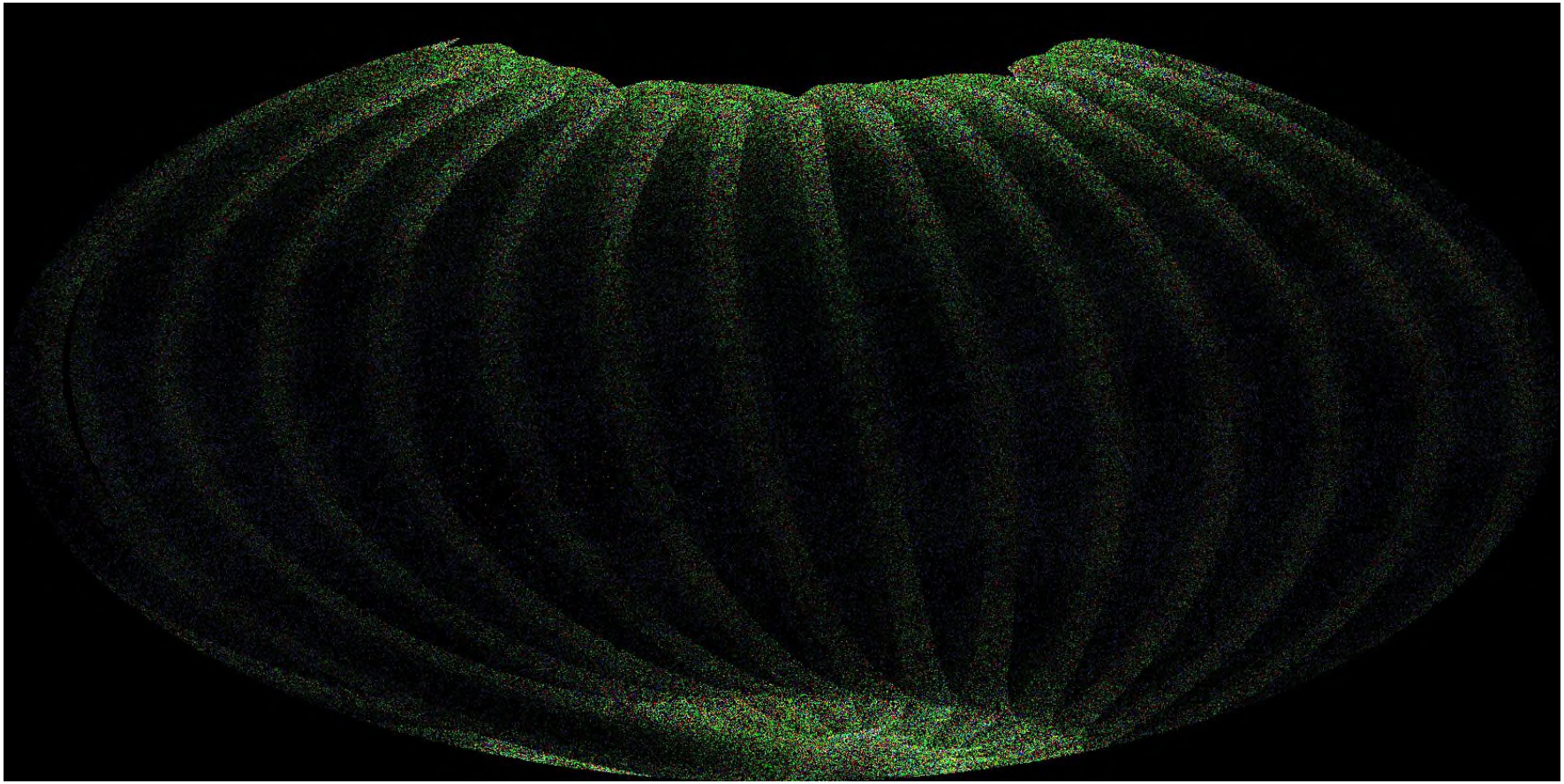
- **The Suomi National Polar-Orbiting Partnership's Visible Infrared Imaging Radiometer Suite (VIIRS)**
  - Instrument Overview
  - VIIRS Day/Night Band (DC/Derecho Storm)
  - VIIRS Land EDRs (Early Cal/Val Period)
- **In-Situ vs. Airborne vs. Satellite BRDF/Albedo**
  - ARM/CART Case Study during ALIVE'05 and CLASIC'07.

Our focus is on global validation of moderate-resolution (> 30 m) land products and the development of long-term data records for studying ecosystem change.

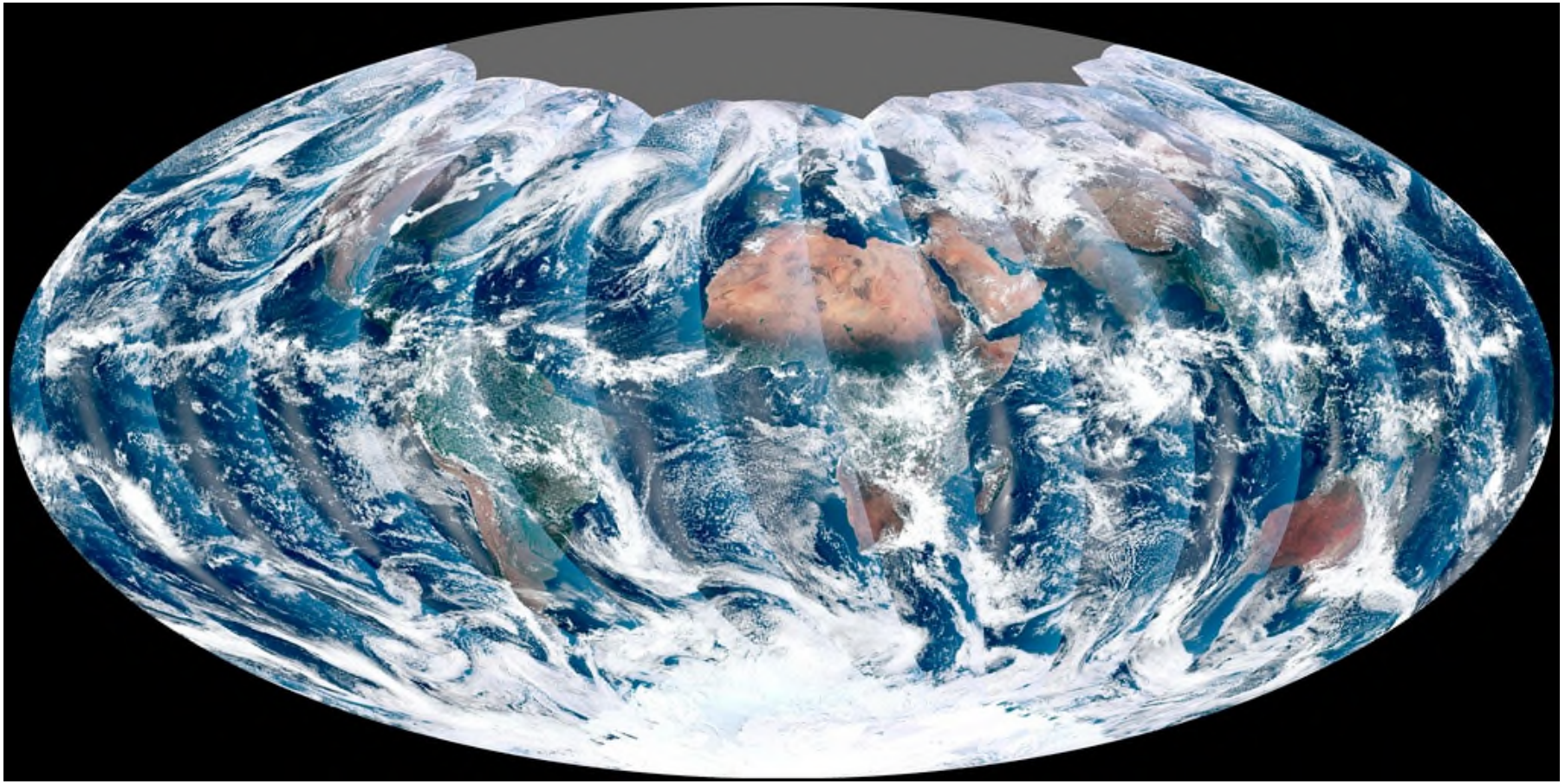
Suomi-NPP with 5 instruments

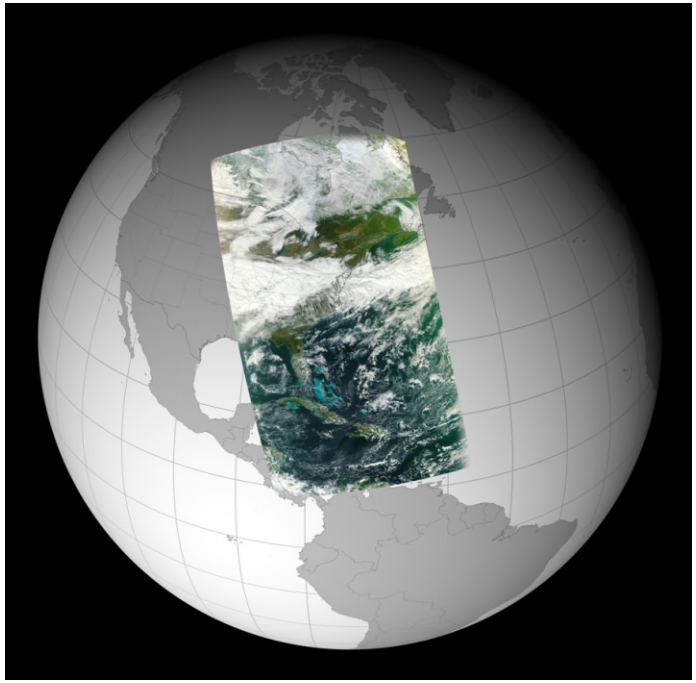


- 10/28/2011: Launched on NPP from VAFB

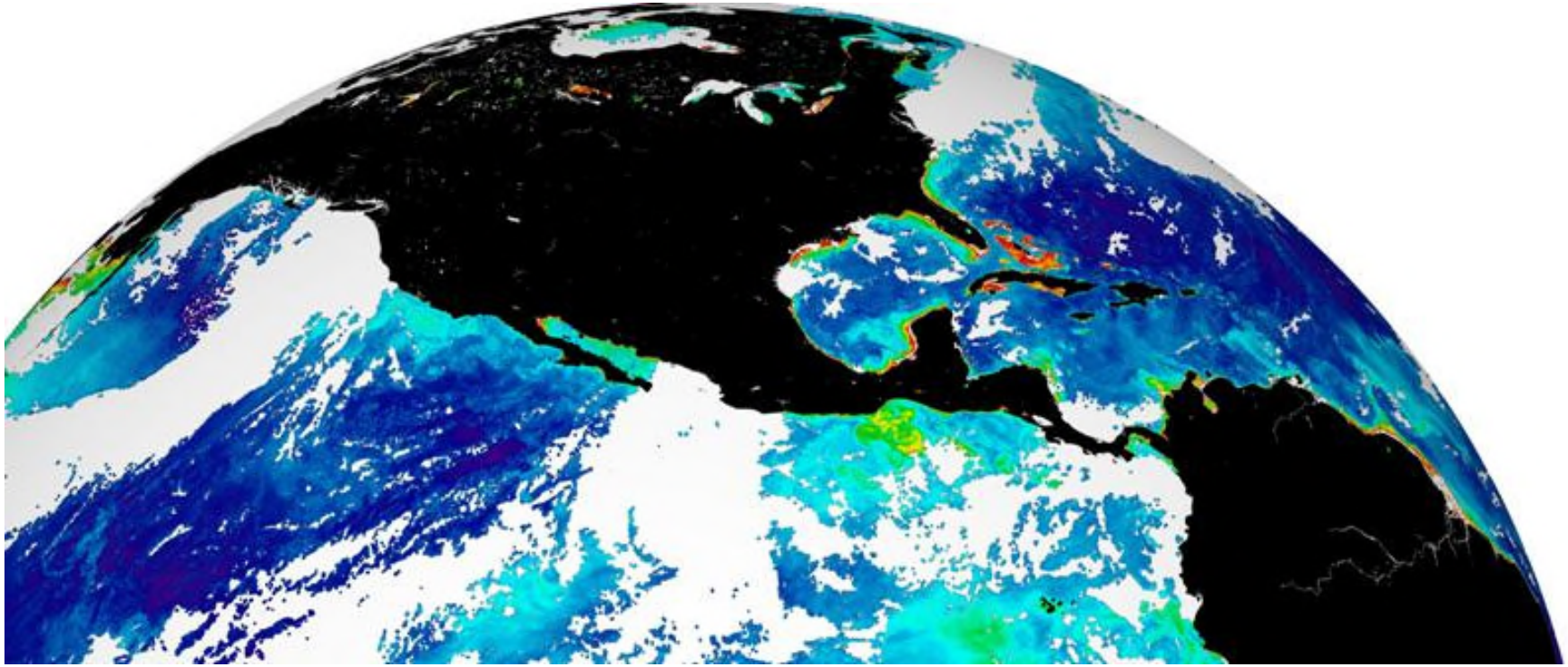


- 10/28/2011: Launched on NPP from VAFB.
- 11/08/2011: VIIRS instrument powered on.



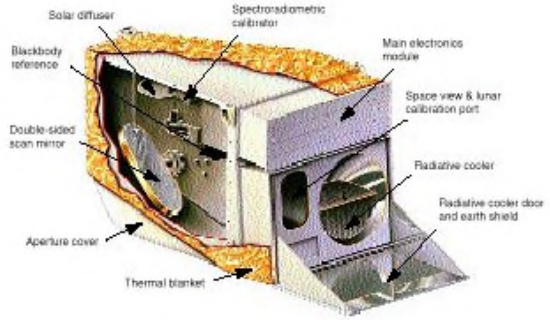


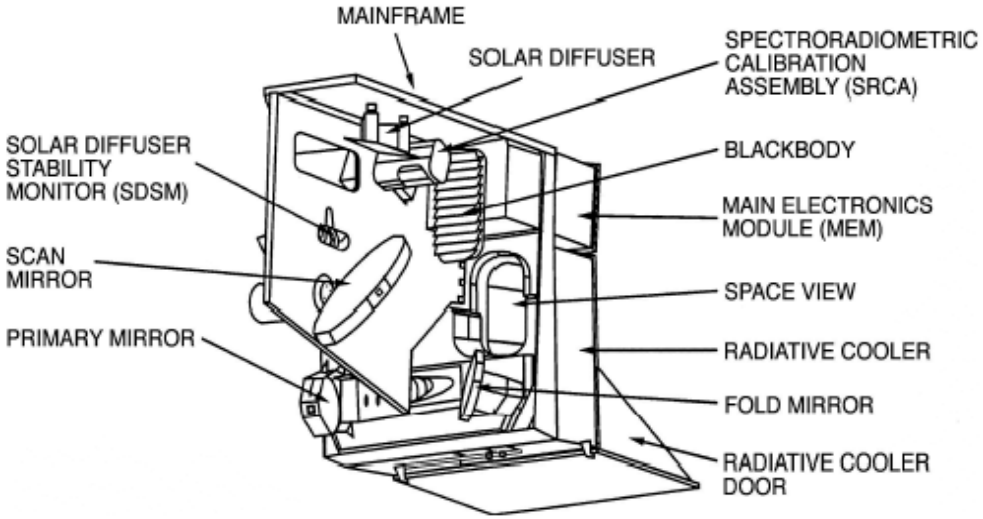
- 10/28/2011: Launched on NPP from VAFB.
- 11/08/2011: VIIRS instrument powered on.
- 11/16/2011: NPP reaches Mission Orbit. All burns are done.
- 11/21/2011: VIIRS Nadir Door opened.



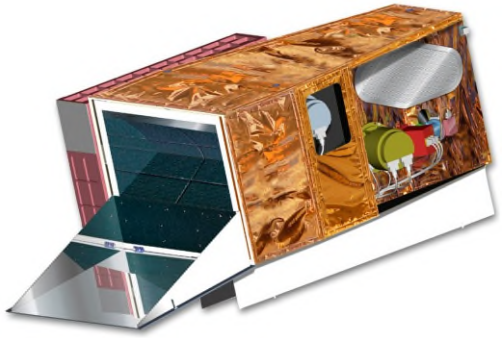
- 10/28/2011: Launched on NPP from VAFB.
- 11/08/2011: VIIRS instrument powered on.
- 11/16/2011: NPP reaches Mission Orbit. All burns are done.
- 11/21/2011: VIIRS Nadir Door opened.
- 11/22/2011: First Ocean Chlorophyll image (from Gene Feldman).

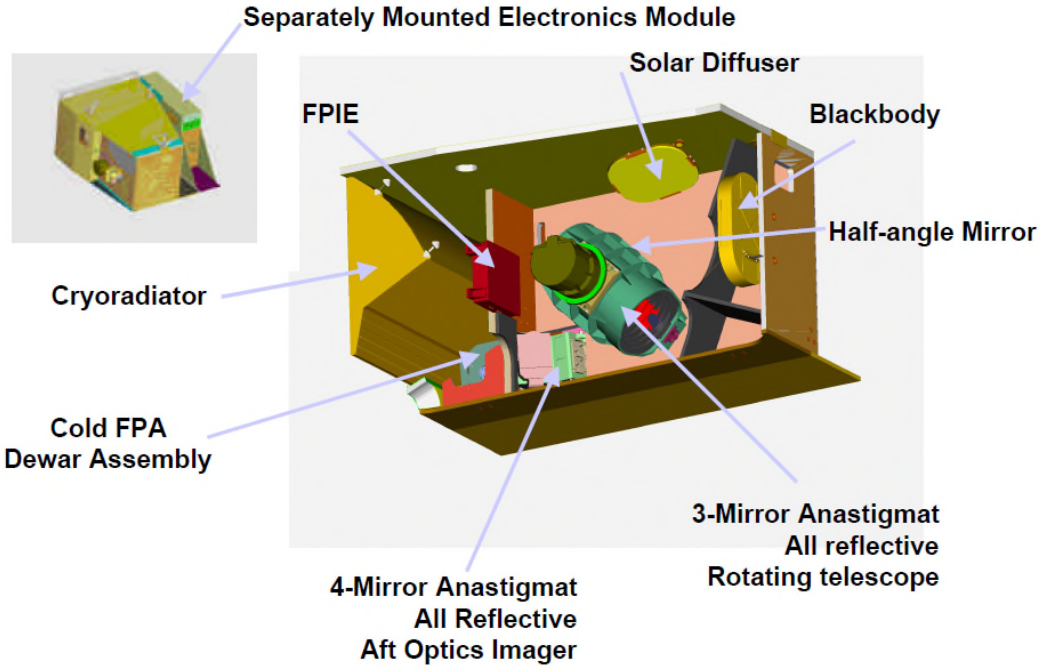
MODIS





VIIRS





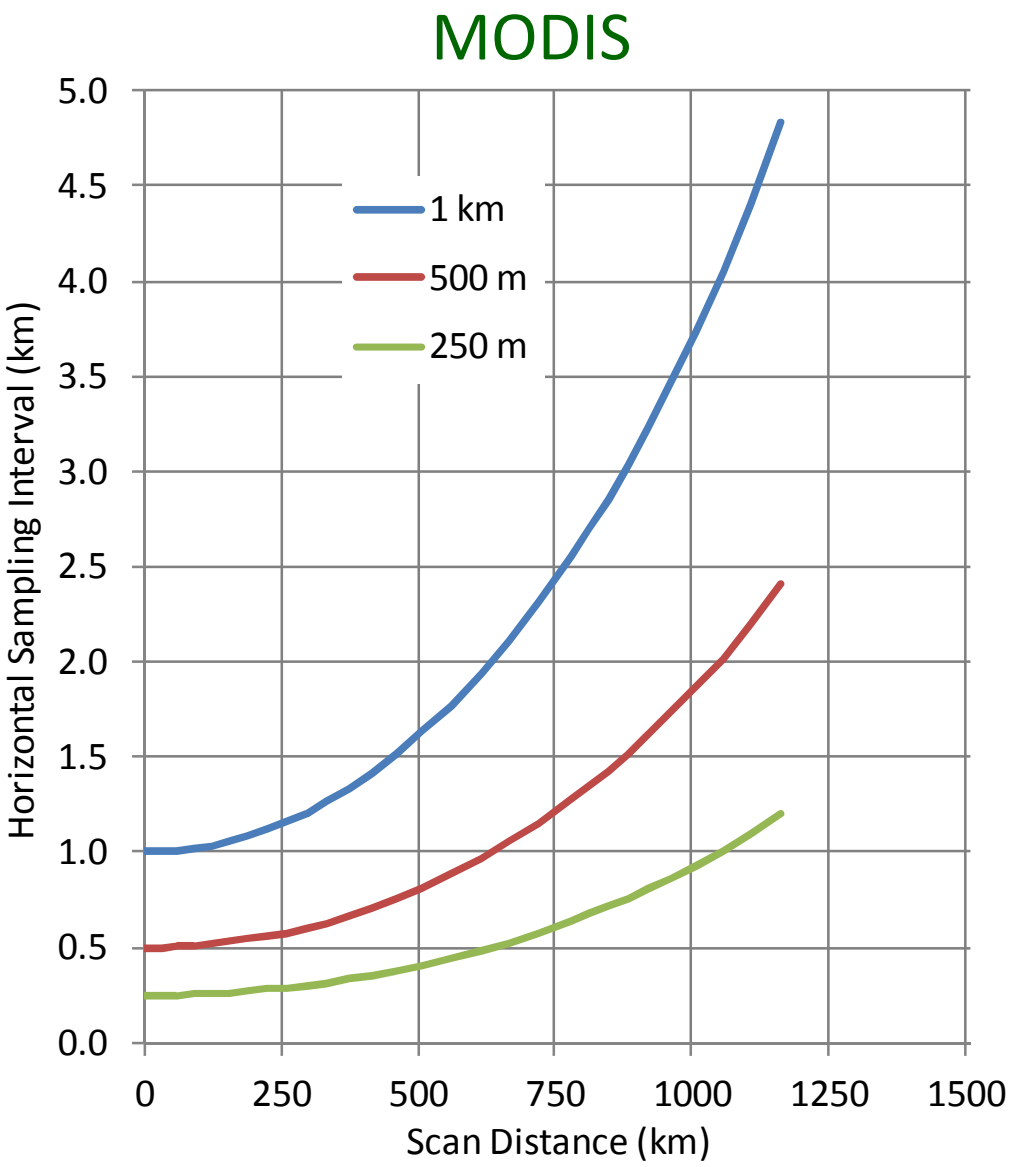
from Wolfe et al.

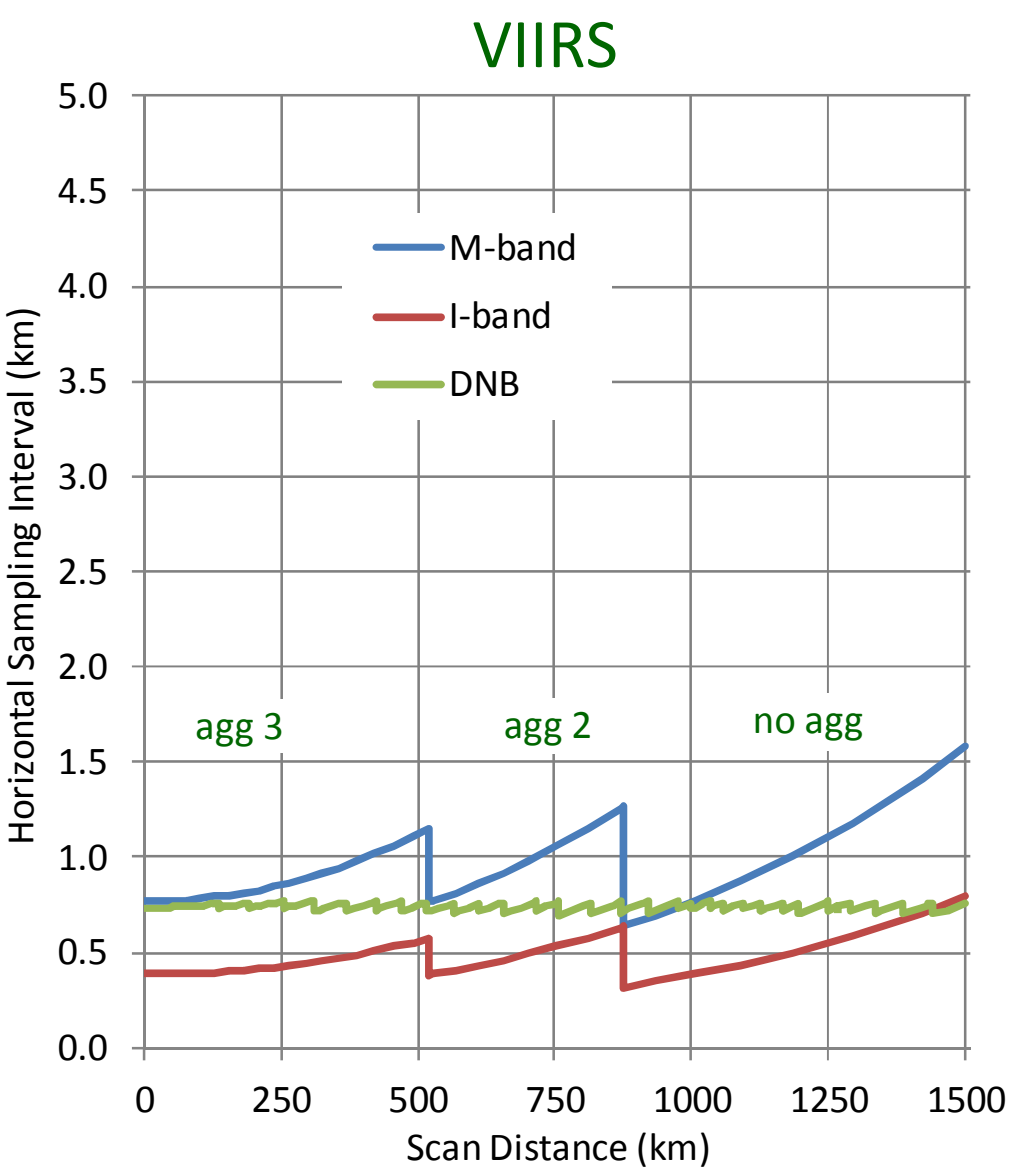
Instrument characteristics

Characteristic	MODIS	VIIRS
Swath width	2340 km	3040 km
Altitude	705 km	824 km
Spectral Bands	36	22
Focal planes	4 (VIS, NIR, MWIR, LWIR)	3 (VIS/NIR, S/MWIR, LWIR)
VIS/NIR	B1, B2 @ 250 m B3, B4 @ 500 m B8 – B12 @ 1 km	I1, I2 @ 375 m M1 – M7 @ 750 m
S/MWIR	B5 – B7 @ 500 m B20 – B26 @ 1 km	I3, I4 @ 375 m M8 – M12 @ 750 m
LWIR	B27 – B36 @ 1 km	I5 @ 375 m M13 – M16 @ 750 m
DNB		DNB @ 750 m

from Wolfe et al.

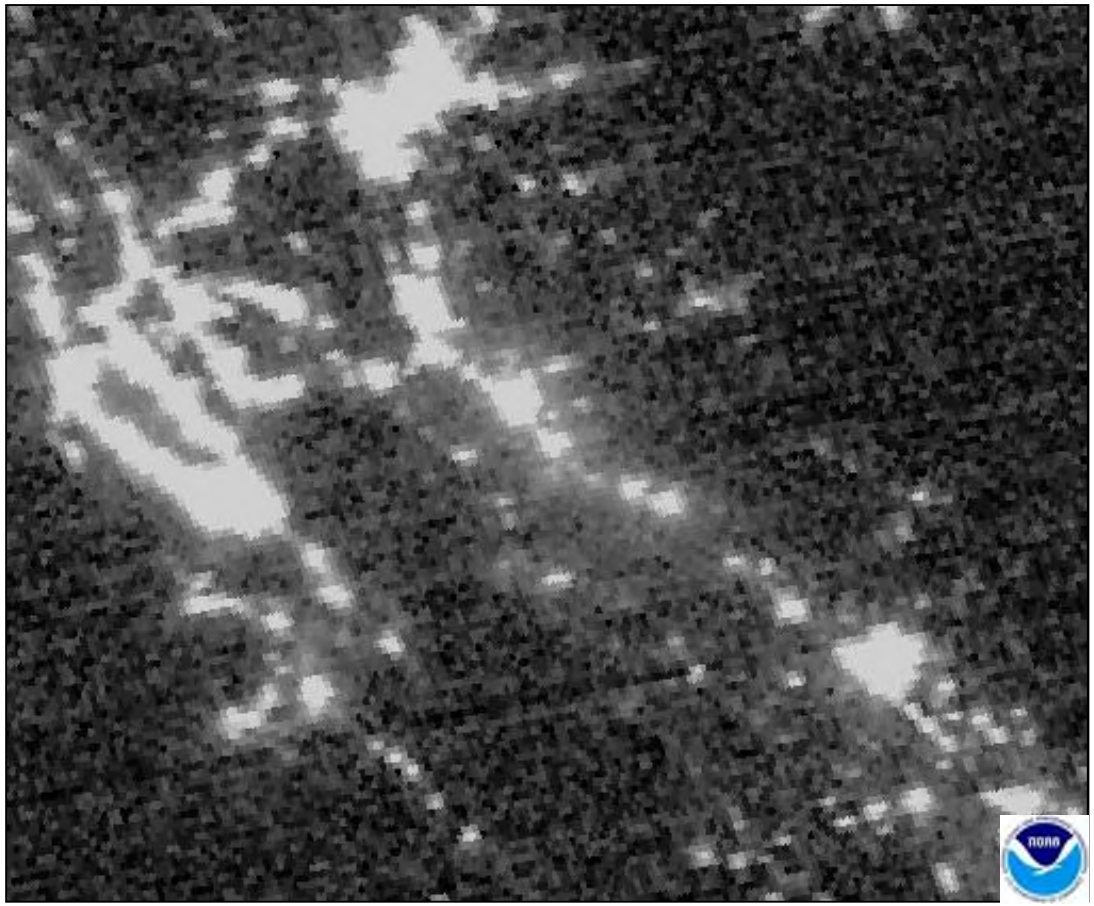
Horizontal sampling interval – Scan

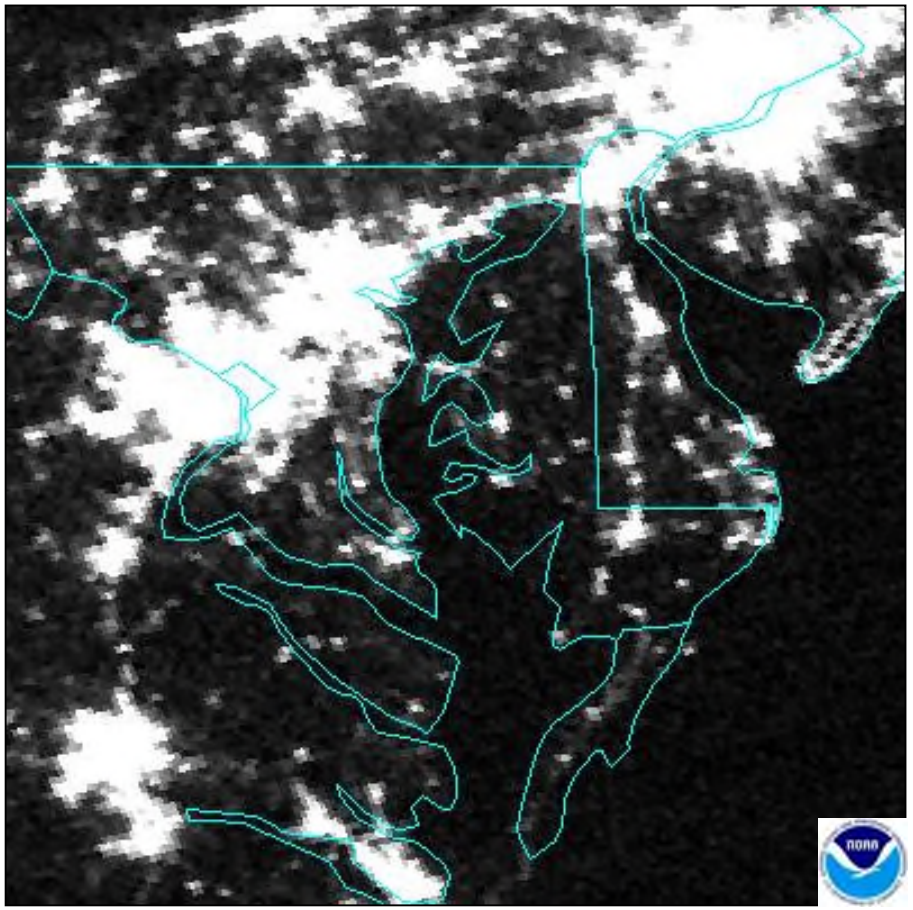




from Wolfe et al.

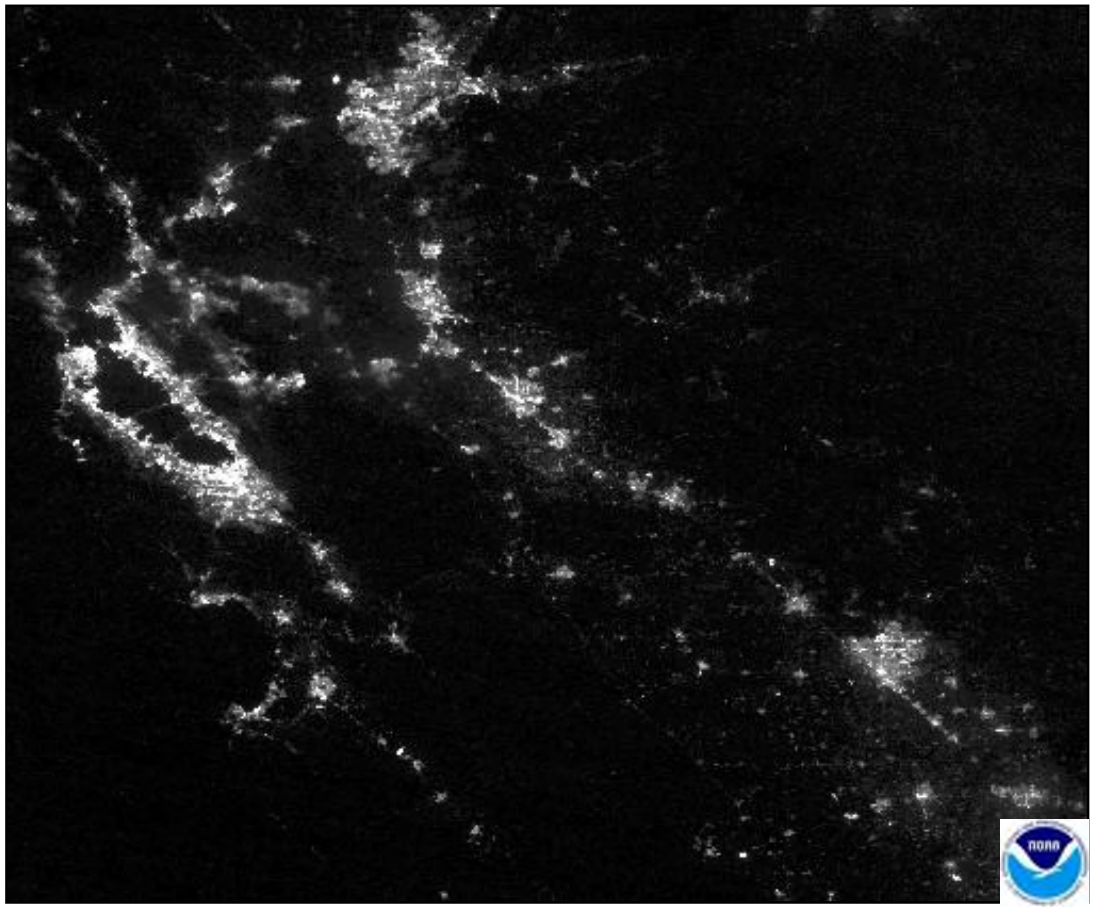
Resolution Improvements: DSMP/OLS vs. VIIRS DNB

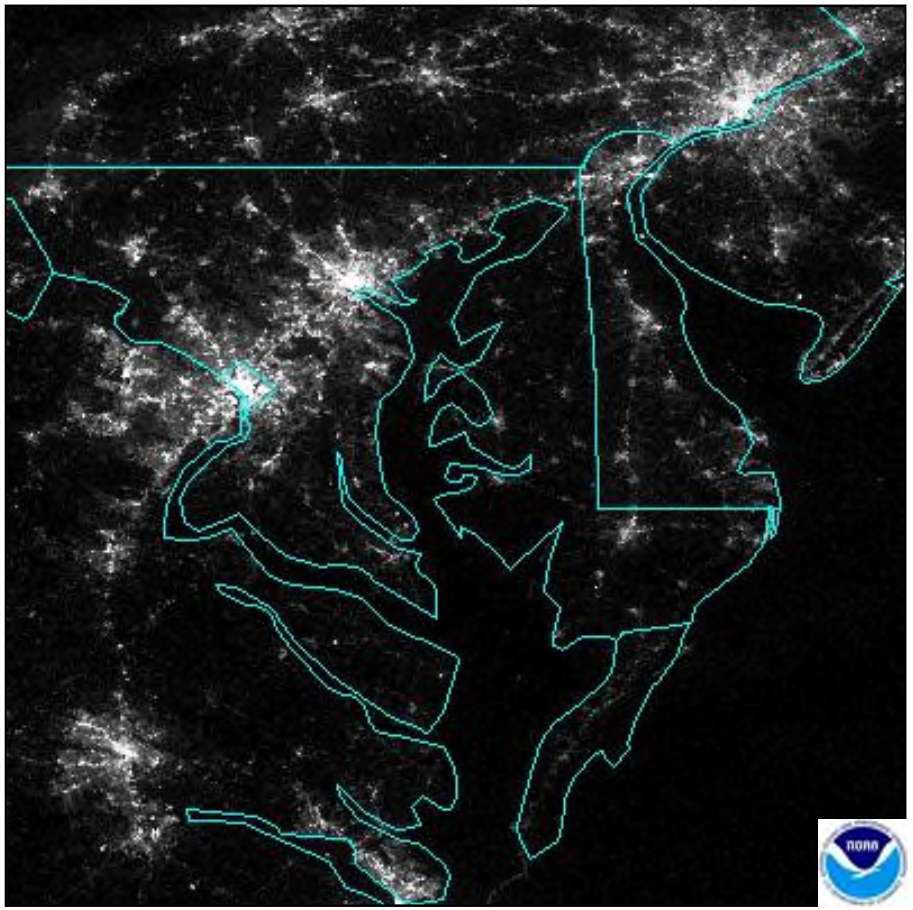




- 740 m instantaneous geometric field of view (DNB) vs. ~5 km for the OLS results in dramatic spatial resolution improvements.
- DNB Imagery courtesy of Steven Miller CIRA/CSU

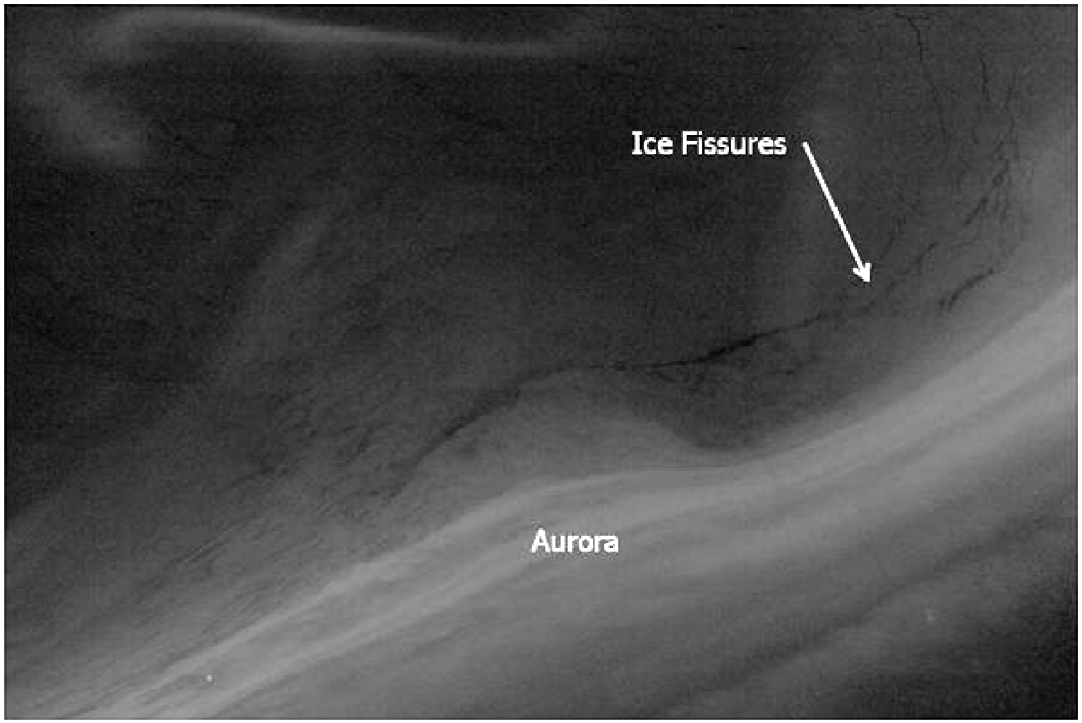
Resolution Improvements: DSMP/OLS vs. VIIRS DNB

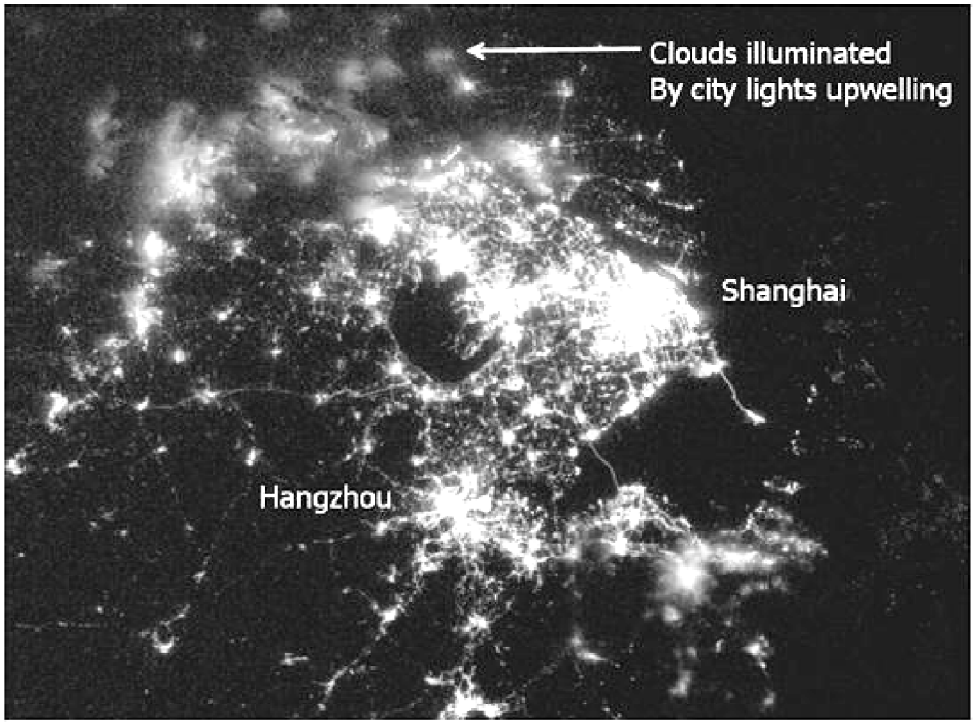


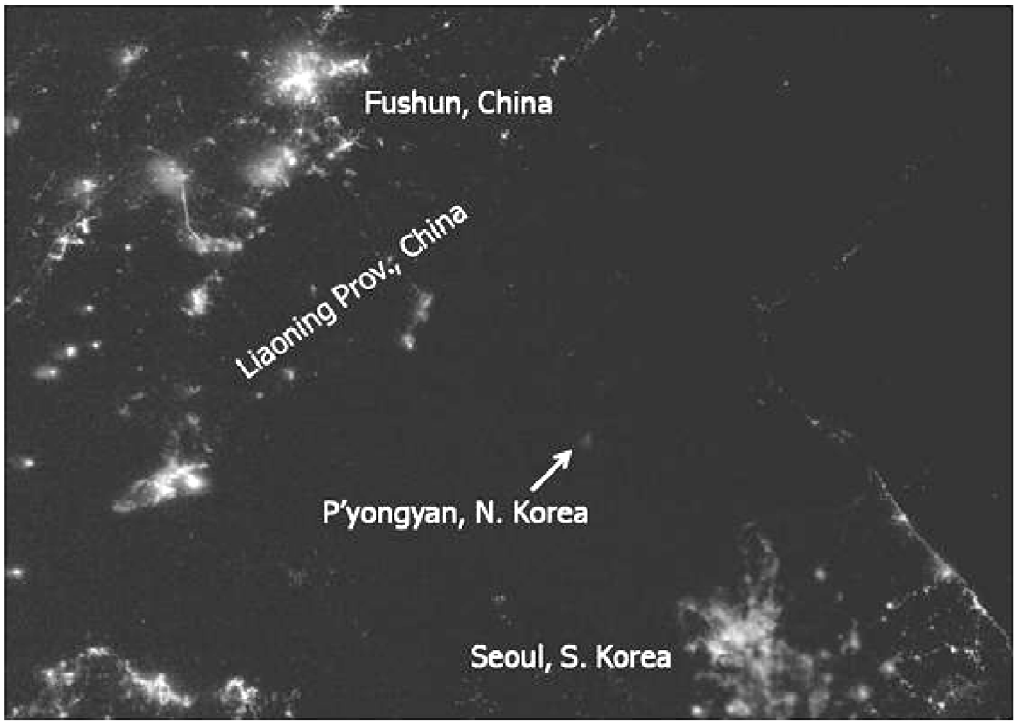


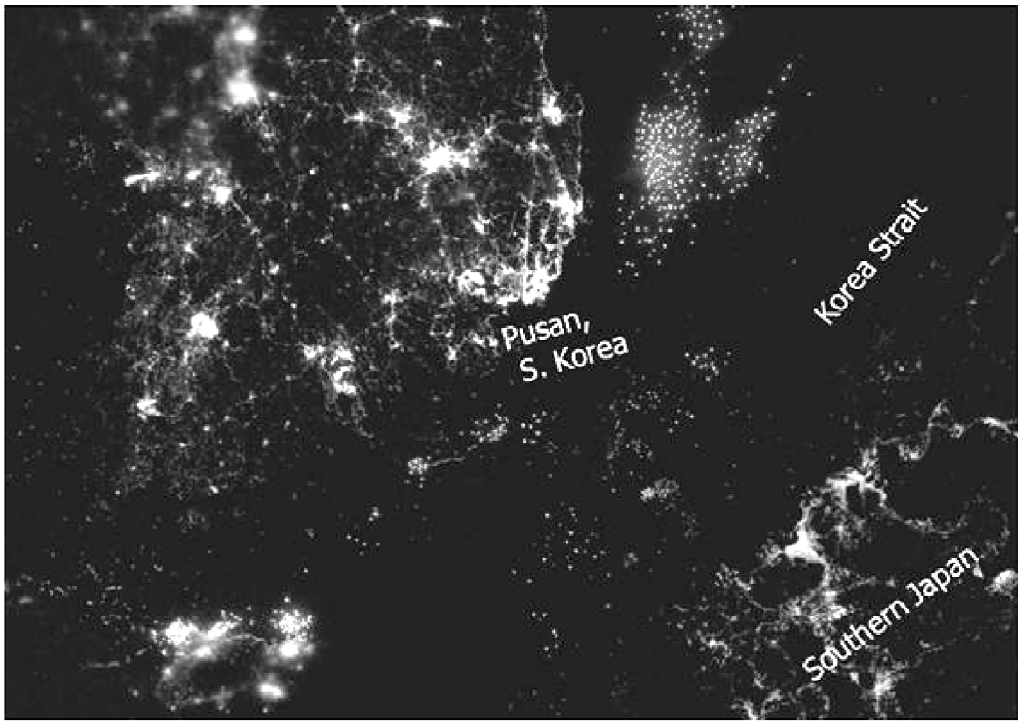
- VIIRS DNB spatial resolution is 14X at nadir and 53X at the edge of scan
- Radiometric resolution across the large dynamic range (7X) using three simultaneously collecting stages, choosing the most sensitive stage in which the pixel is not saturated.

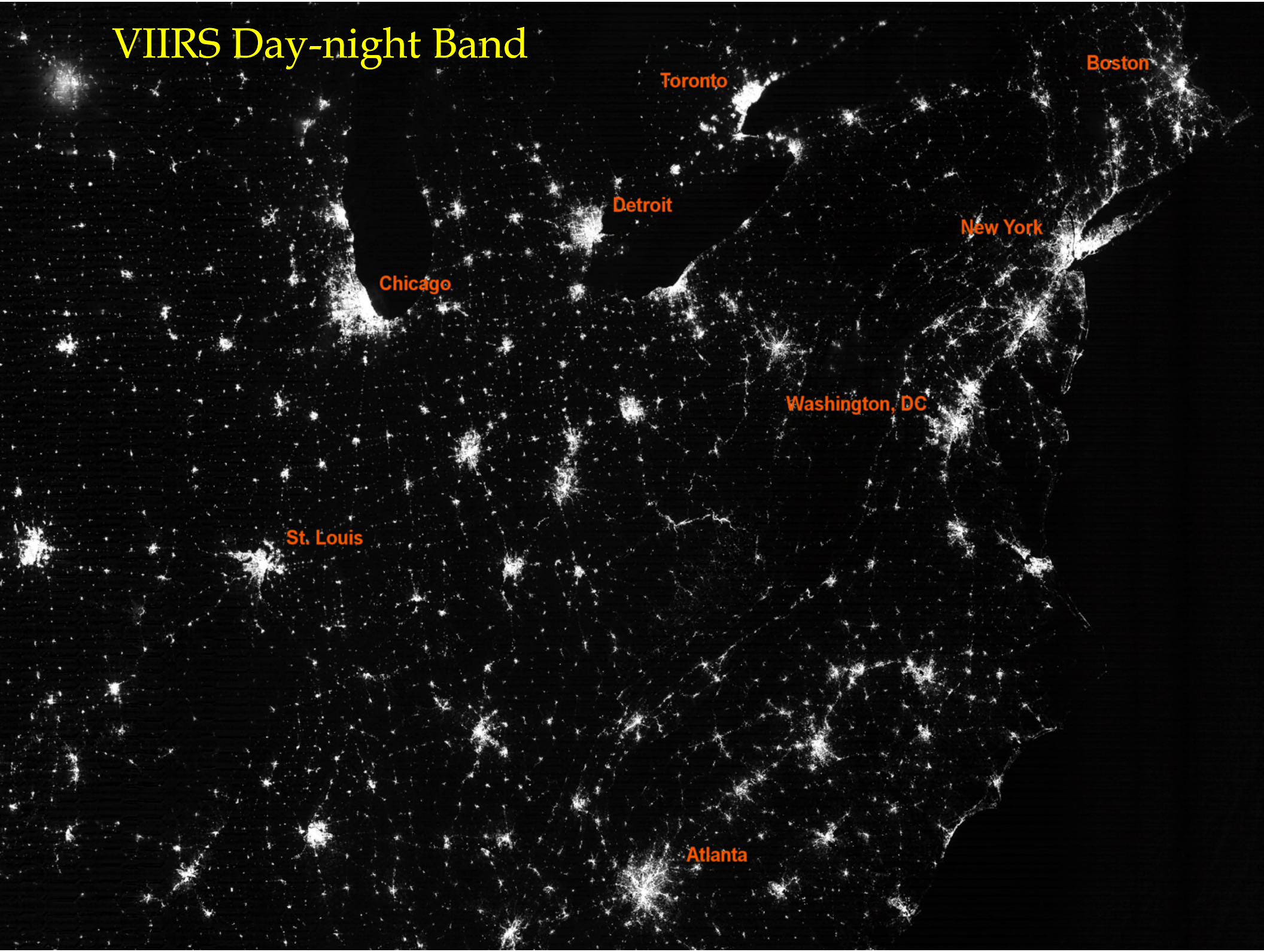
11/28/2011: First Look at VIIRS Day Night Band (from NGAS)










VIIRS Day-night Band
Toronto
Boston
Detroit
New York
Chicago
Washington, DC
St. Louis
Atlanta

(Launch +8 months) DC/Derecho Storm

(Front Page Article on 7/5/2012)

The Washington Post

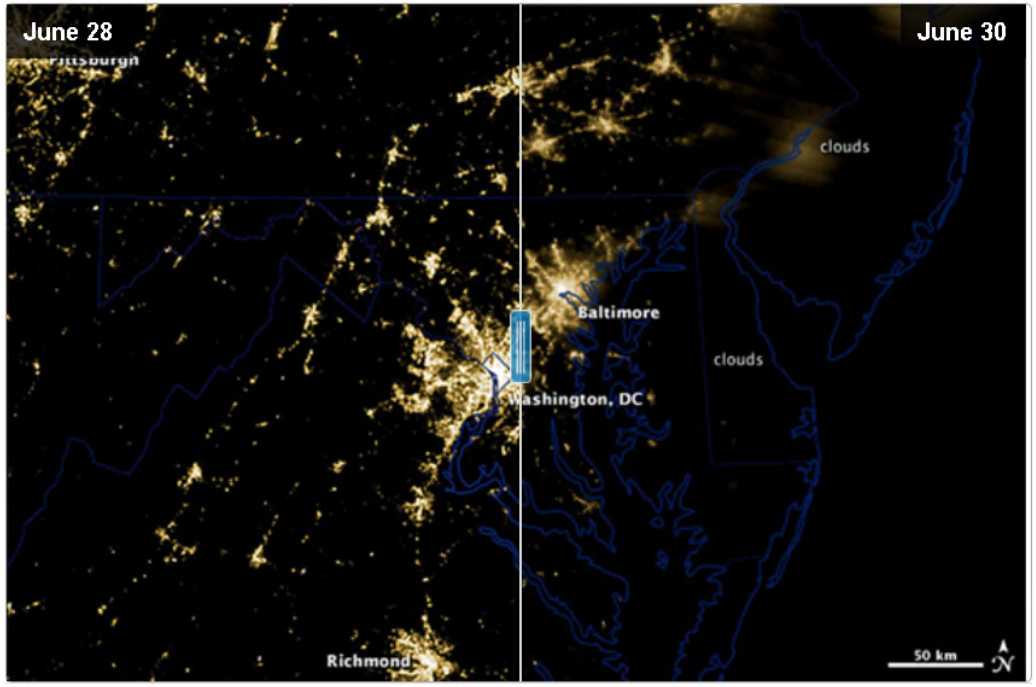
In the News MLB All-Star game Nicolas Cage photo Lance Armstrong Peter O'Toole retires

Tweet 129 Share Follow PostLocal:

D.C. storm's aftermath: A look from space

Use the slider to compare satellite images from NASA of the mid-Atlantic region before and after the derecho passed through, knocking out power to more than a million people in the D.C. region.

Drag the slider to the right to see the before image, and drag it to the left to see the after image.

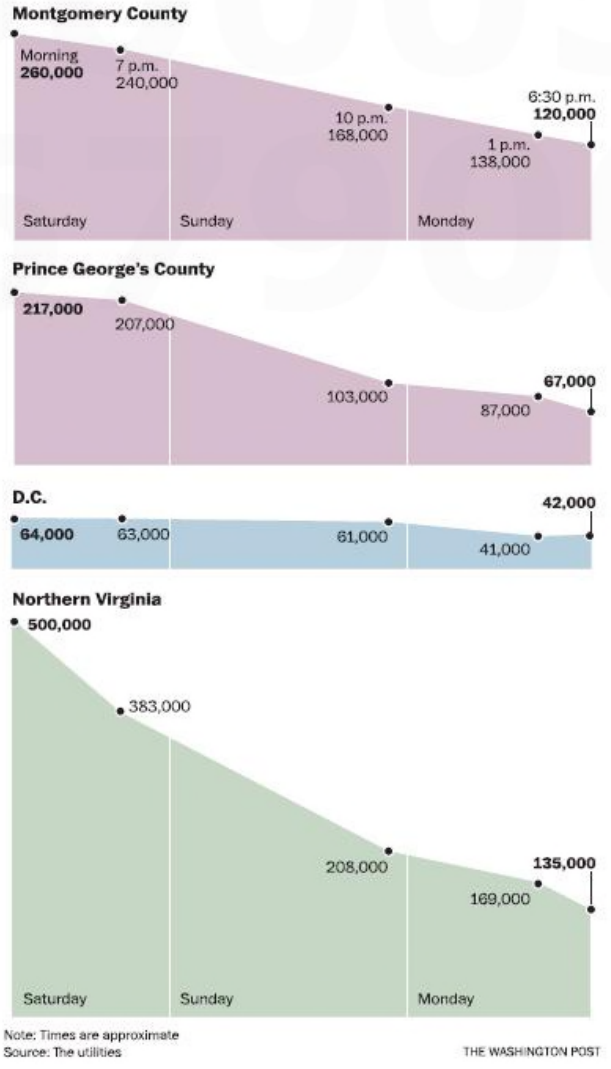


SATELLITE IMAGES: NASA via AP. GRAPHIC: Wilson Andrews and Emily Ingram - The Washington Post. Published July 5, 2012.

Power to some people

Friday's storm knocked out power to more than 1 million customers in the Washington region. As of early Monday evening, hundreds of thousands remained without electricity.

ESTIMATED NUMBER OF CUSTOMERS WITHOUT POWER



Note: Times are approximate
Source: The utilities

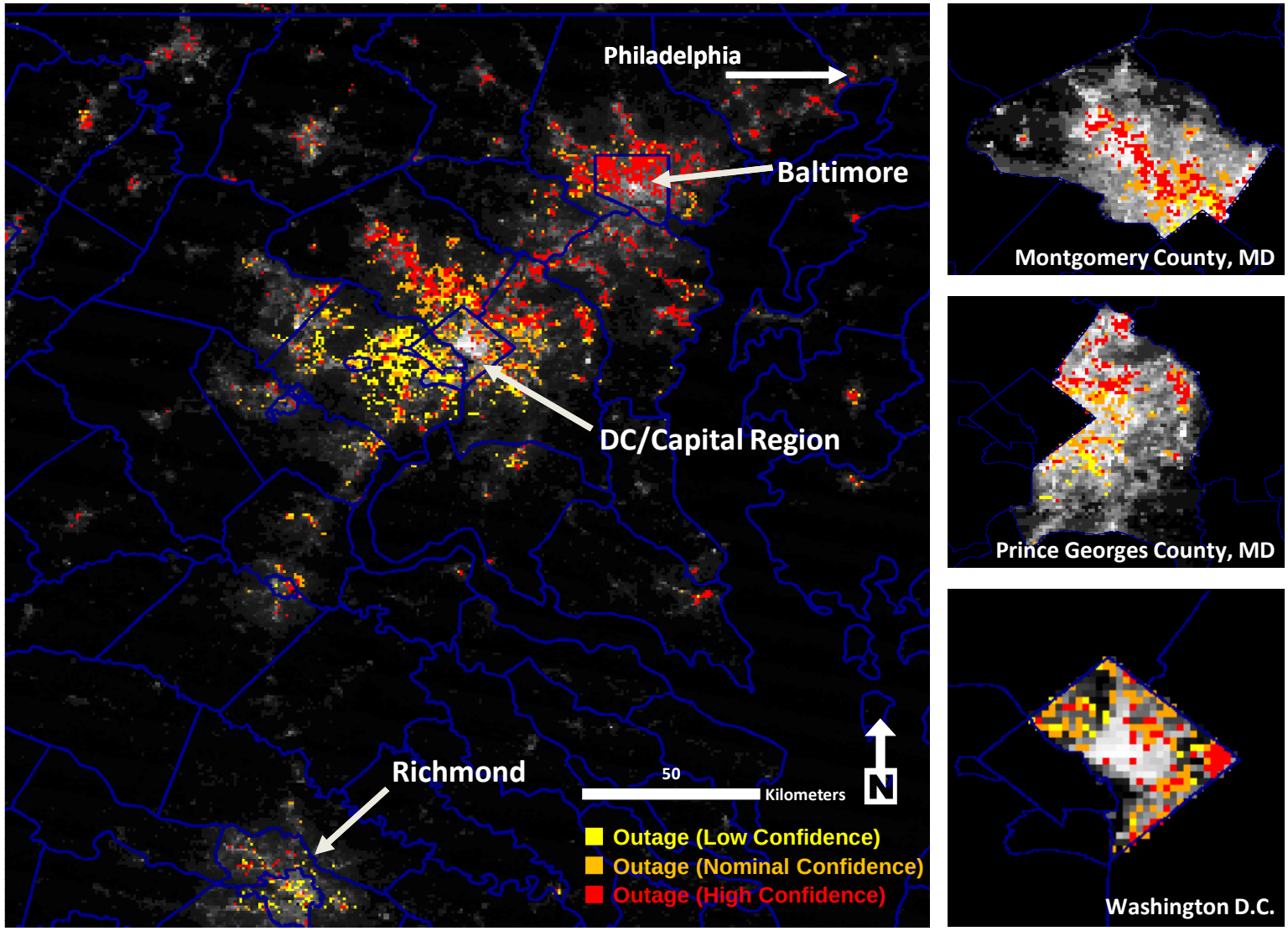
THE WASHINGTON POST

For outreach and disaster response, it is essential to produce images quickly...

Detection of Urban Light Outages using the VIIRS Day/Night Band: An Early Case Study on the D.C. Derecho Storm

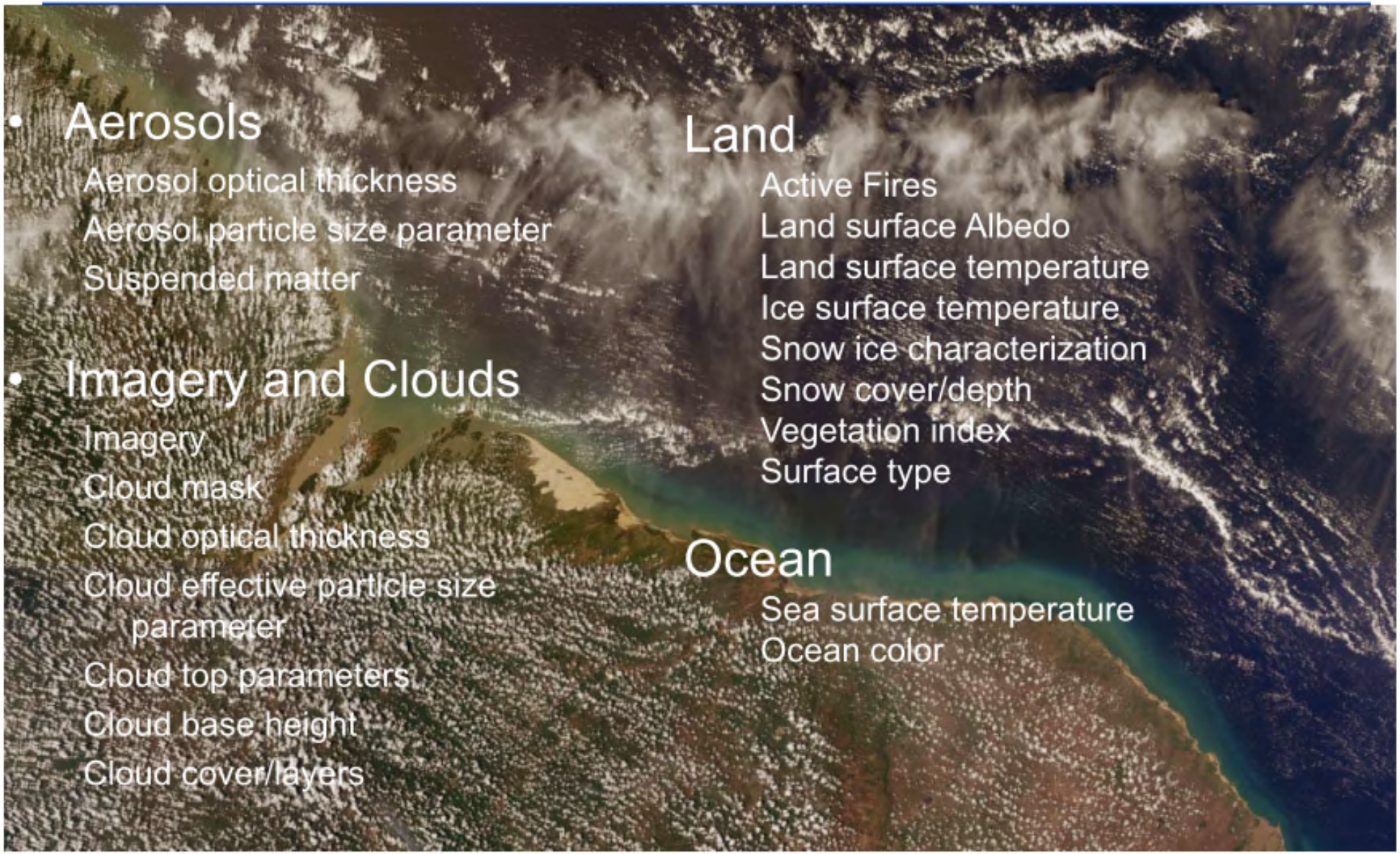
Miguel O. Román, Robert E. Wolfe, and Edward J. Masuoka (GSFC/619)

VIIRS nighttime calibrated radiances acquired 1-day after the June 30, 2012 D.C. Derecho storm were used to create outdoor light outage maps, using an analytical approach that considers urban area extent, clouds and observation quality.



Spatial distribution of light outages in Washington, DC and vicinity after the D.C. Derecho Storm.

VIIRS EDRs


• Aerosols
Aerosol optical thickness
Aerosol particle size parameter
Suspended matter
• Imagery and Clouds
Imagery
Cloud mask
Cloud optical thickness
Cloud effective particle size parameter
Cloud top parameters
Cloud base height
Cloud cover/layers
Land
Active Fires
Land surface Albedo
Land surface temperature
Ice surface temperature
Snow ice characterization
Snow cover/depth
Vegetation index
Surface type
Ocean
Sea surface temperature
Ocean color

National Aeronautics and Space Administration
Goddard Space Flight Center

GO

Sciences and Exploration

NPP- Land Product Evaluation and Testing Element

VIIRS Land Product Quality Assessment

Visible/Infrared Imager/Radiometer Suite

Home | Browse | Time Series | Land Products | QA Info | Alg Updates/Eval | Links | Early Images

Welcome to the NPP VIIRS Land Product Quality Assessment

The objective of the VIIRS (Visible Infrared Imaging Spectro Radiometer Suite) Land Product QA is to evaluate and document the science quality of products made from the remotely sensed data acquired using VIIRS. Results of quality assessment of samples of VIIRS Land products made at IDPS (Interface Data Processing System) and results of evaluation of improvements to the VIIRS Land Science algorithms derived by analyzing the products made at Land PEATE (Product Evaluation and Testing Element) using the new algorithms are placed on the web pages located at this site. NPP (National Polar Orbiting Earth Sattellite System Proparatory Project) satellite was launched on Oct. 28, 2011. Evaluation of products from the IDPS OPS algorithms, and the Land PEATE adjusted version of the IDPS OPS algorithms run at Land PEATE and of the science algorithm improvements are done at LDOPE (Land Data Operational Product Evaluation). Results from LDOPE's evaluation of the pre-launch and at launch version of the IDPS algorithms done using simulated or proxy MODIS data are posted on the Algorithm Updates/Evaluation section of this web page. This web page is constantly evolving. For global browse images from immediate post-launch period please click on the Brows menu at the top of this page. Please direct your questions and comments to Sadashiva Devadiga.

What's New

- NPP Launch, Friday, Oct.28, 2011.
- VIIRS started acquiring earth view data on Nov 21, 2011
- The VIIRS cooler door opened on Jan 18, 2012. Thermal bands are now cooled down and the thermal data is useful starting after Jan. 20, 2012.
- VIIRS Beta quality products available from LAADS

Goddard SPACE FLIGHT CENTER

Responsible NASA Official : Edward Masuoka
Content Owner: Sadashiva Devadiga
Web Curator: Demi Feng

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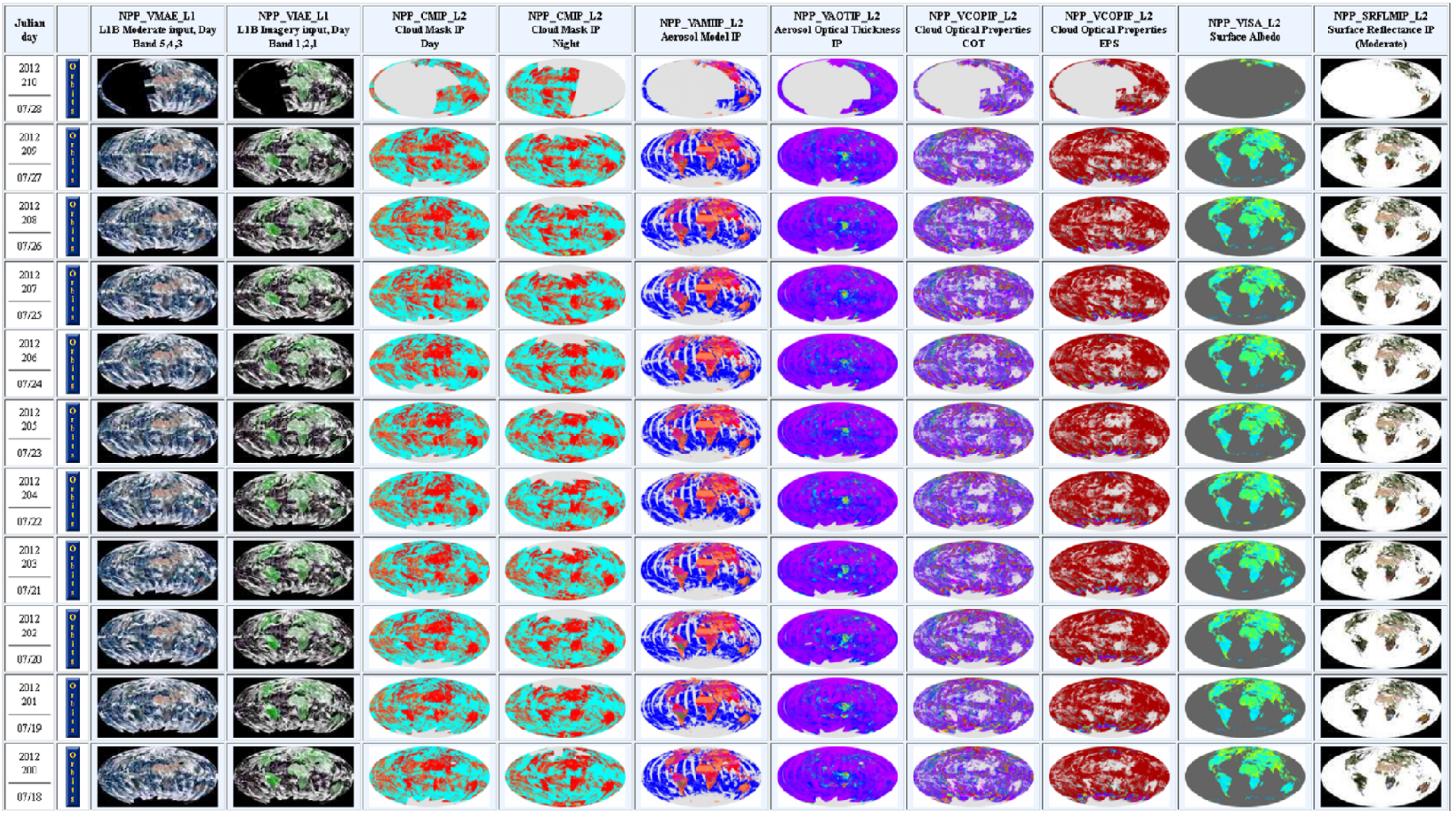
Contact Us
Page Last Updated: Jan. 26, 2012

(..see our BSRN poster)

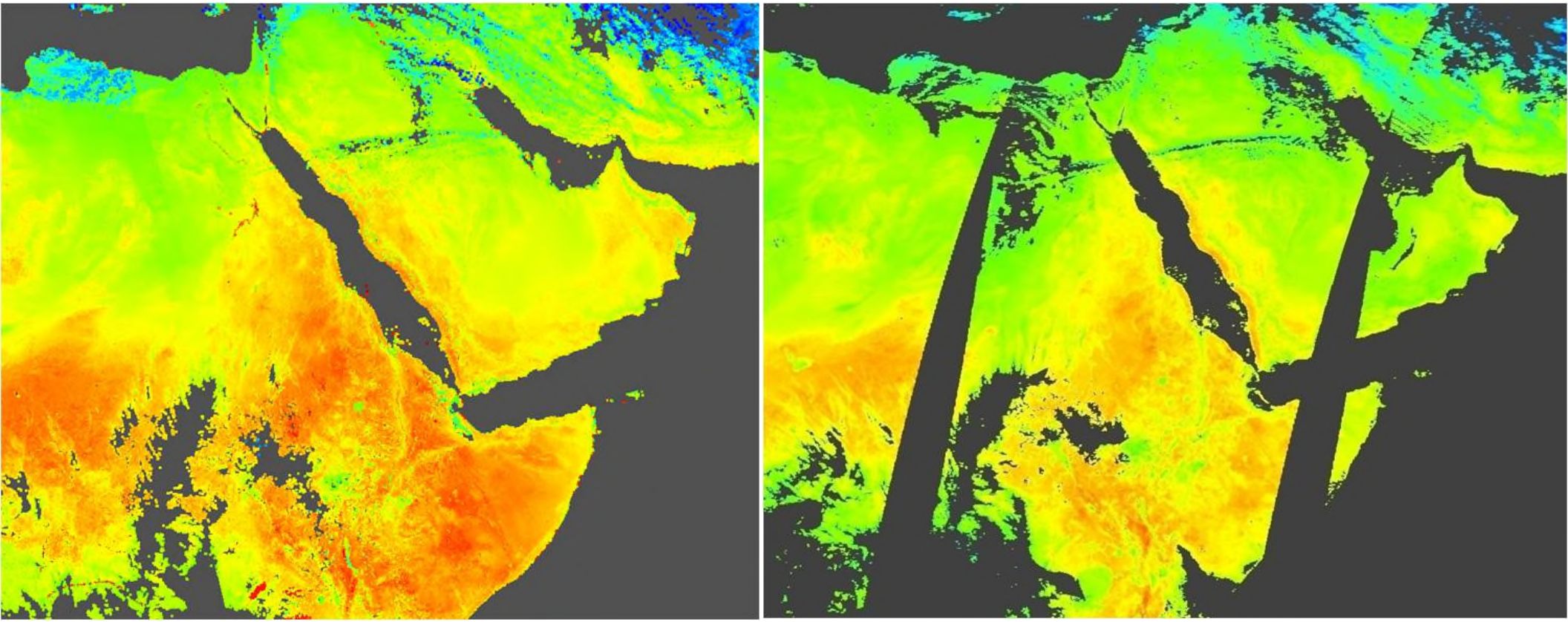
Suomi-NPP Global Browse (DOY 200-210, 2012)



http://landweb.nascom.nasa.gov/cgi-bin/NPP/browse/NPPbrowse.cgi

Land Surface Temperature (LST) EDR

- ***Description:*** Provides land surface skin temperature at the satellite overpass time under cloud-free conditions.
- ***Retrieval Strategy:*** ***Multichannel Linear Regression Approach; Surface Type Dependency***
- ***Current Challenges****:* LST EDR does not provide dynamic **land surface emissivity** per the current MODIS "day-night" algorithm. This is a valuable product and should be continued in the JPSS era.

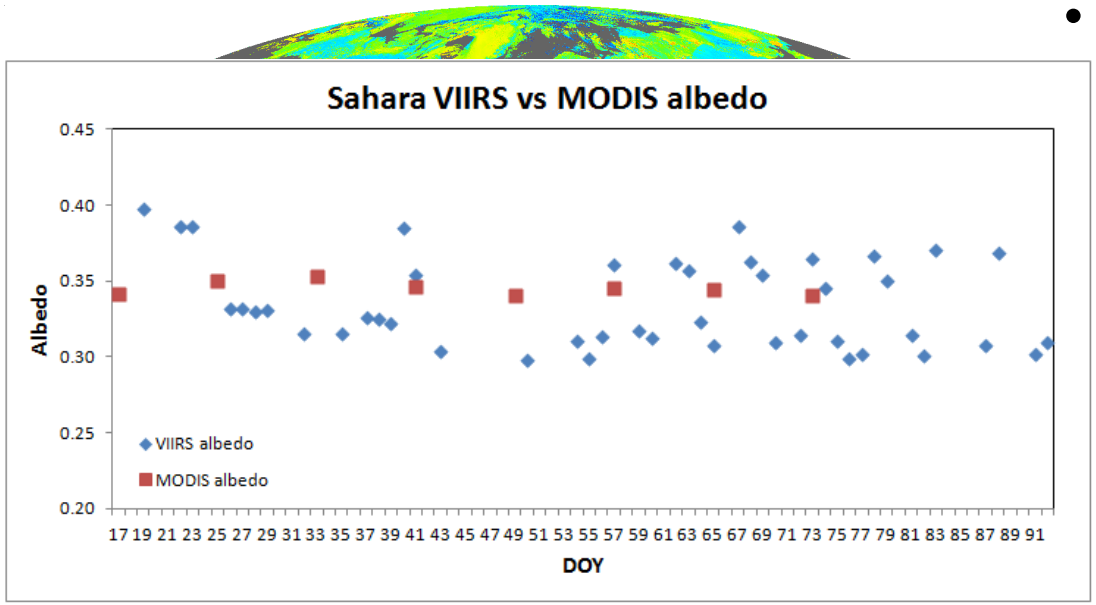


NPP_VLST_Level_2, (01/26/2012)
Land PEATE-Adjusted

MYD11C1D_Aqua_LST, (01/26/2012)
Collection V005

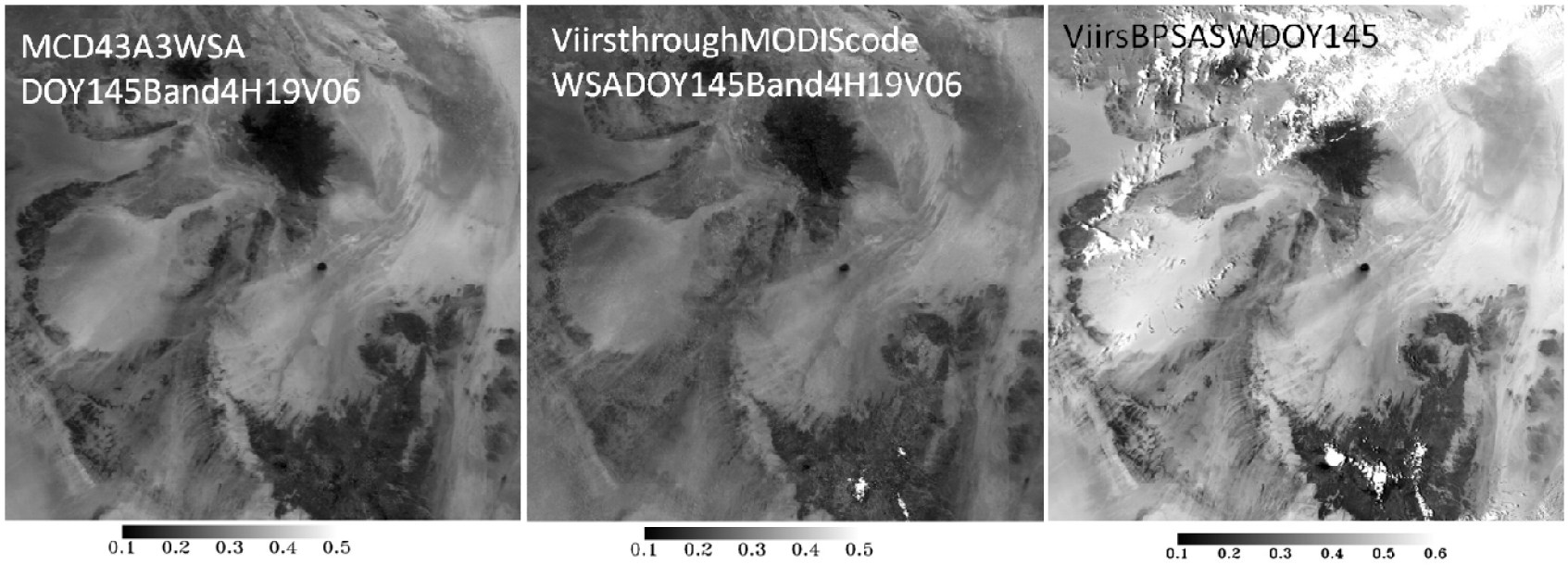
Surface Albedo EDR

- ***Description:*** Provides broadband surface albedo (0.3-5.0μm) on a daily basis under cloud-free conditions.



- ***Retrieval Strategies:***
  - ***Single-day BPSA*** *(Uses TOA radiances and pre-computed radiative transfer model information)*
  - ***Multidate DPSA*** *(Uses MODIS heritage)*

Current Challenges*:* Both Climate and NWP models call for a representation of the surface radiation in terms of at least PAR (0.3-0.7μm) and NIR (0.7-5.0μm) radiation.

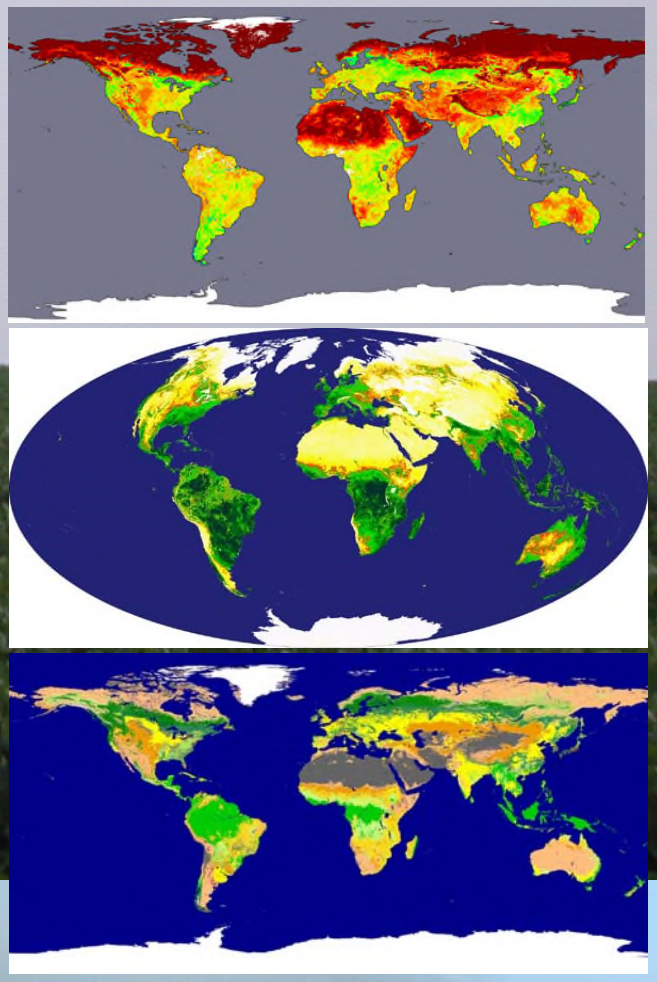


Overarching Goal: To directly map through measurement uncertainties from sensors to products.

Relating plot-level measurements

airborne measurements…

…to global land products.



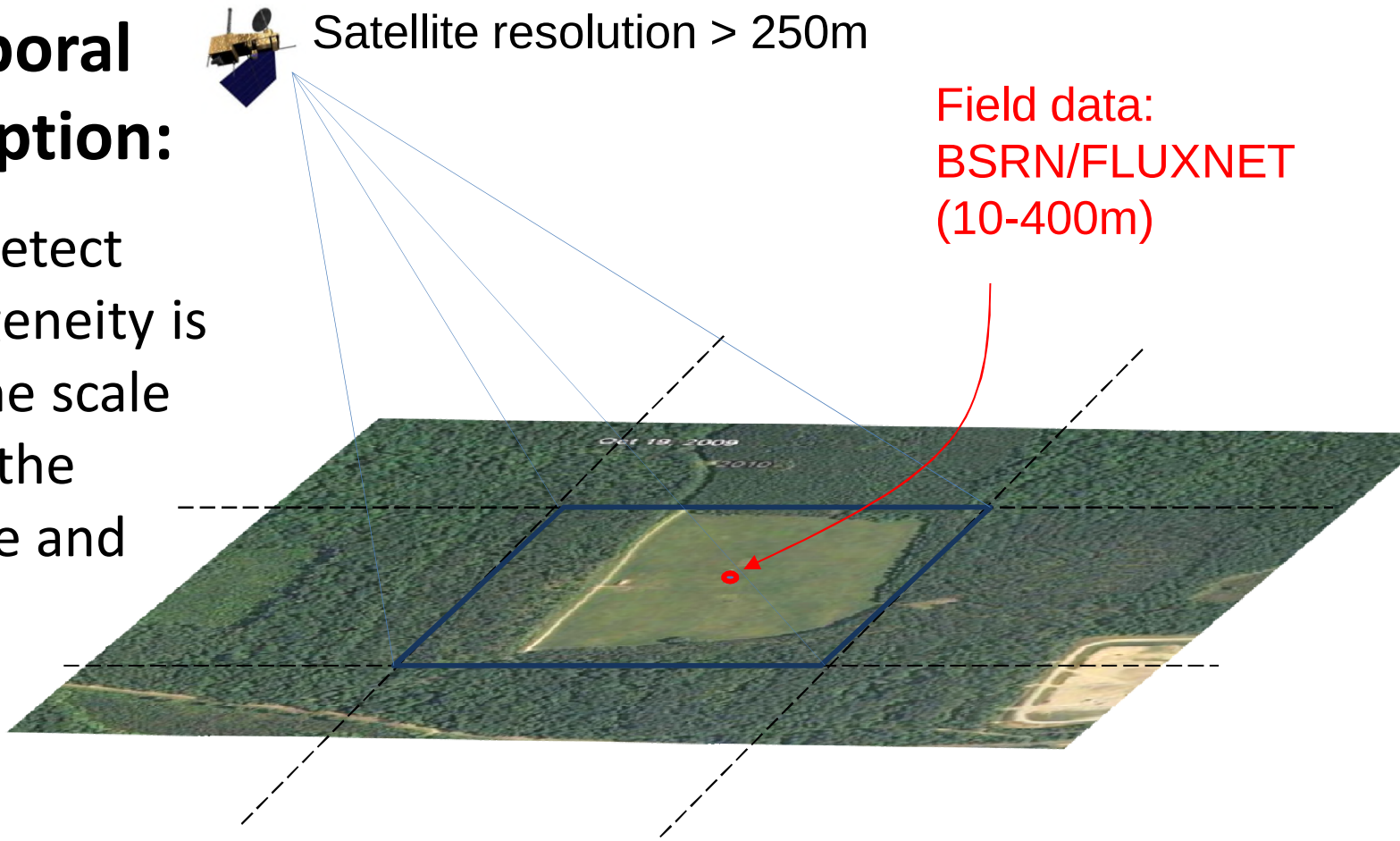
Bondville, IL

Assumptions underlying the use of Semi-Empirical BRDF models

(1) Linear-Mixture Assumption: Satellite-derived BRDF 'shapes' of archetypal ecosystem types can implicitly capture surface heterogeneities.

(2) Spatiotemporal Scaling Assumption:

The potential to detect structural heterogeneity is independent of the scale corresponding to the satellite's pixel size and repeat cycle.



(Lewis, 1995)
(Pinty et al., 2002)

ARM Southern Great Plains Central Facility (SGPCF)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D20105, doi:10.1029/2008JD010062, 2008

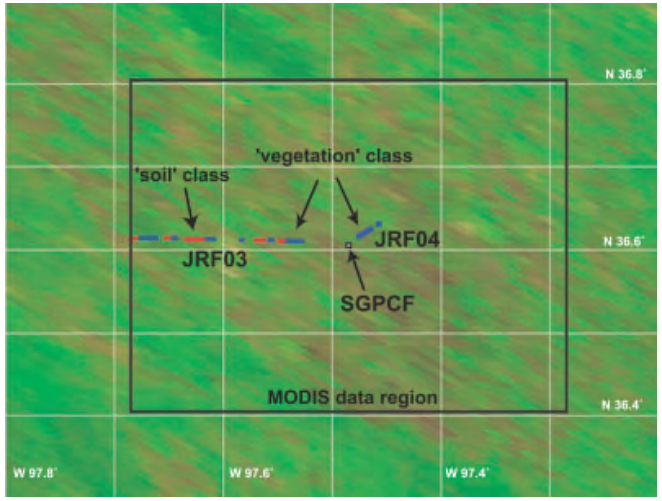
Click Here for Full Article

Surface BRDF estimation from an aircraft compared to MODIS and ground estimates at the Southern Great Plains site

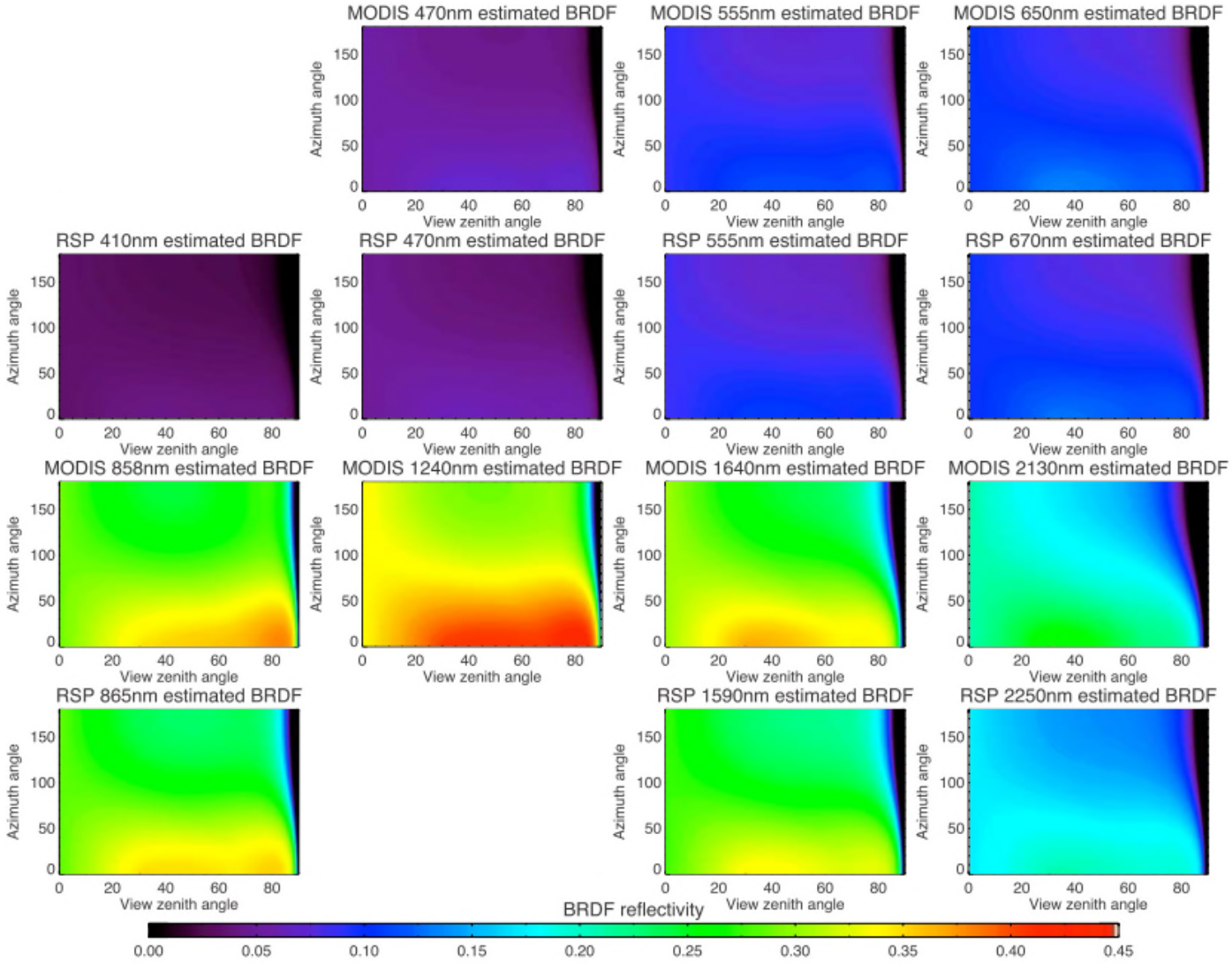
Kirk D. Knobelspiesse,[1] Brian Cairns,[1,2] Beat Schmid,[3] Miguel O. Román,[4] and Crystal B. Schaaf[4]

Table 1. Low Altitude ALIVE Flight Segments Used for Surface Characterization

	JRF3	JRF4
Date	09/16/2005	09/16/2005
Start time, UTC	16:32:25	22:09:32
Number of RSP scans	270	41
J-31 Altitude above sea level	510 m	475 m
Relative sensor-solar azimuth	−45°	156°
Solar zenith angle	43°	62°
AERONET $\tau_a(\lambda = 500$ nm)	0.07	0.05
AATS-14 $\tau_a(\lambda = 499$ nm)	0.06	0.05
sky conditions	clear	clear



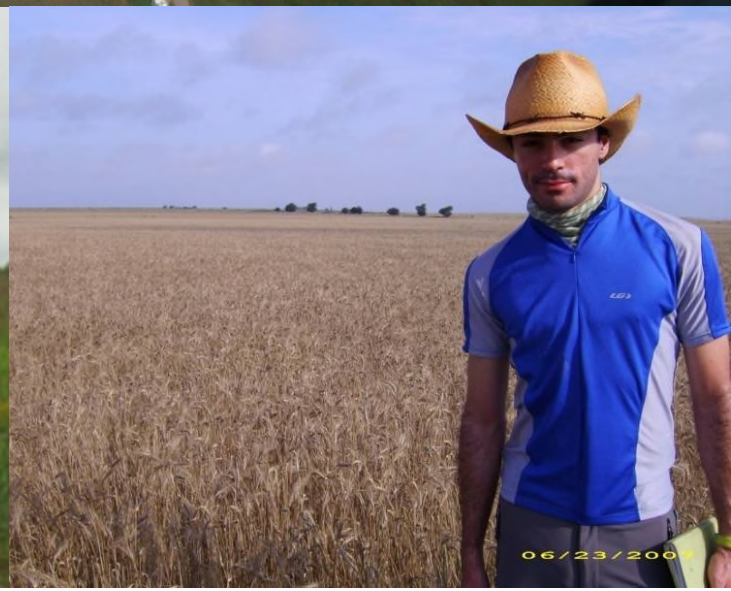
BRDF approximation for MODIS (first and third rows) and RSP (second and fourth rows) during ALIVE'05 campaign. These results are for the 'all' surface type class with a solar zenith angle of 30°



CLASIC'07

NASA

Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

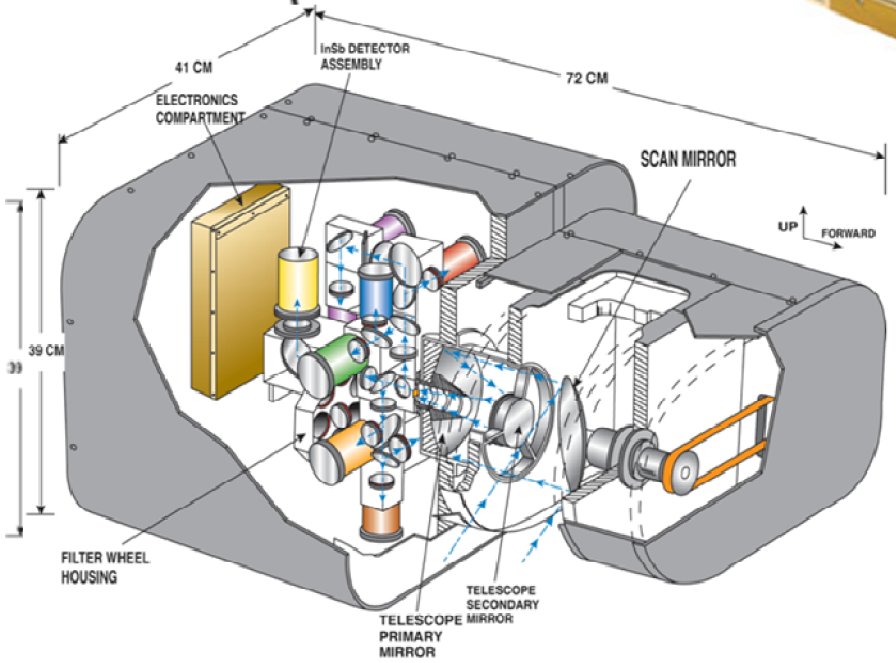


NASA P-3, CAR, & CANS

NASA P-3B Aircraft

Laboratory Calibration of CAR

CANS

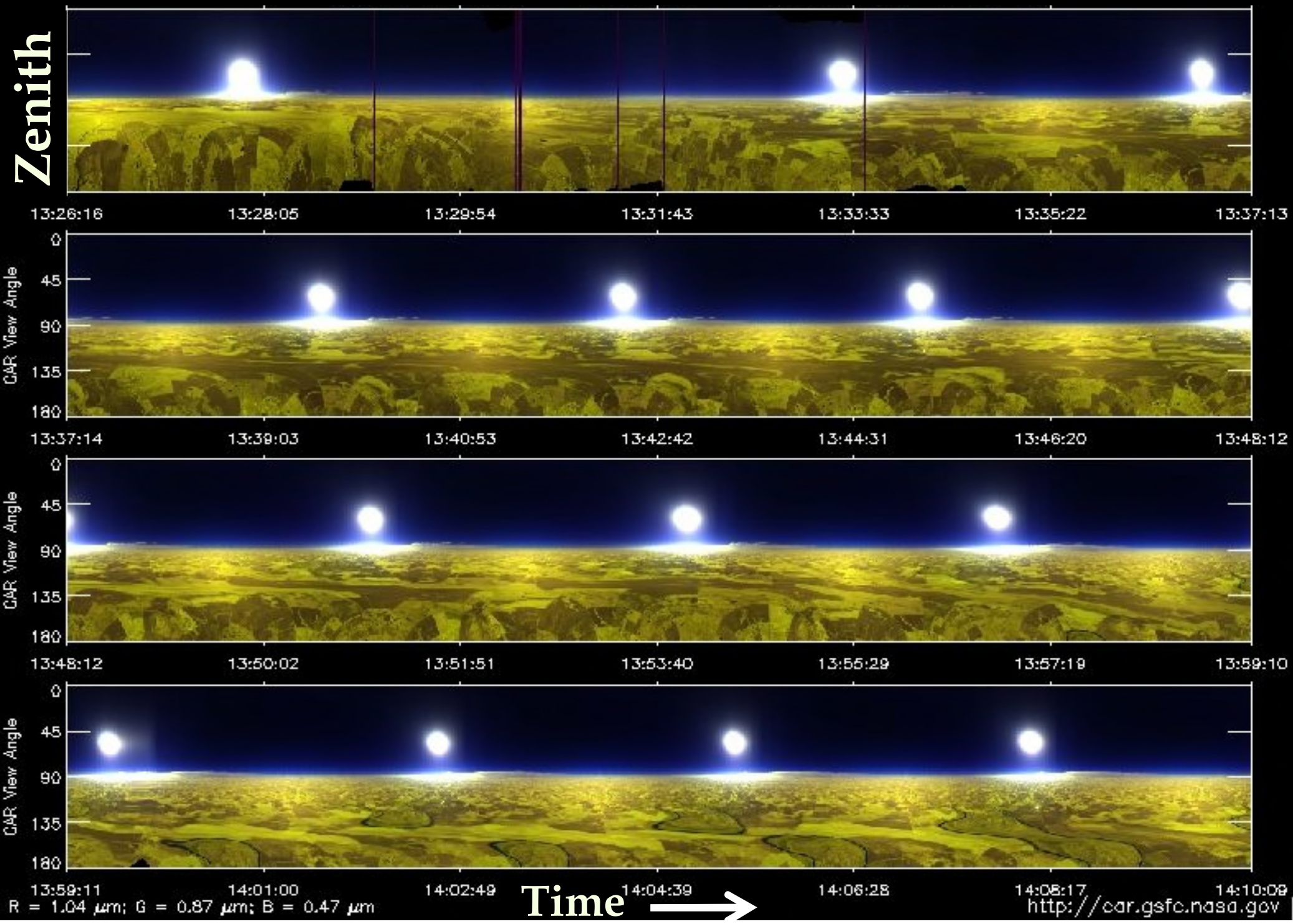


Cloud Absortion Radiometer (CAR) Parameters

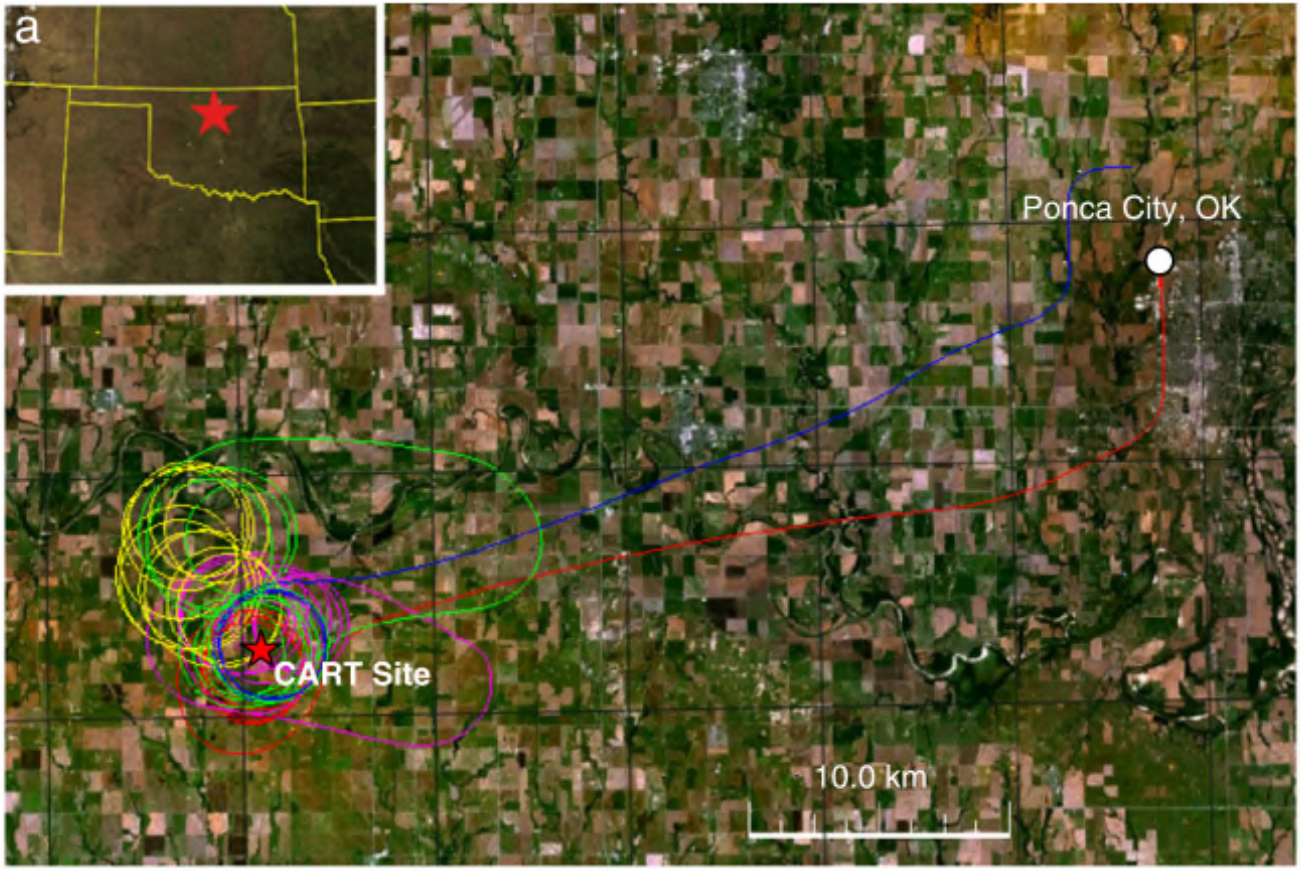
Angular scan range	190°
Instantaneous field of view	17.5 mrad (1°)
Pixels per scan line	382
Scan rate	1.67 scan lines per second (100 rpm)
Spectral channels (μm; bandwidth (FWHM))	14 [a] (8 continuously sampled and last six in filter wheel): 0.340(0.009), 0.381(0.006), 0.472(0.021), 0.682(0.022), 0.870(0.022), 1.036(0.022), 1.219(0.022), 1.273(0.023), 1.556(0.032), 1.656(0.045), 1.737(0.040), 2.103(0.044), 2.205(0.042), 2.302(0.043)

http://car.gsfc.nasa.gov/

CAR Quick-Look Image: CLASIC Flight #1928

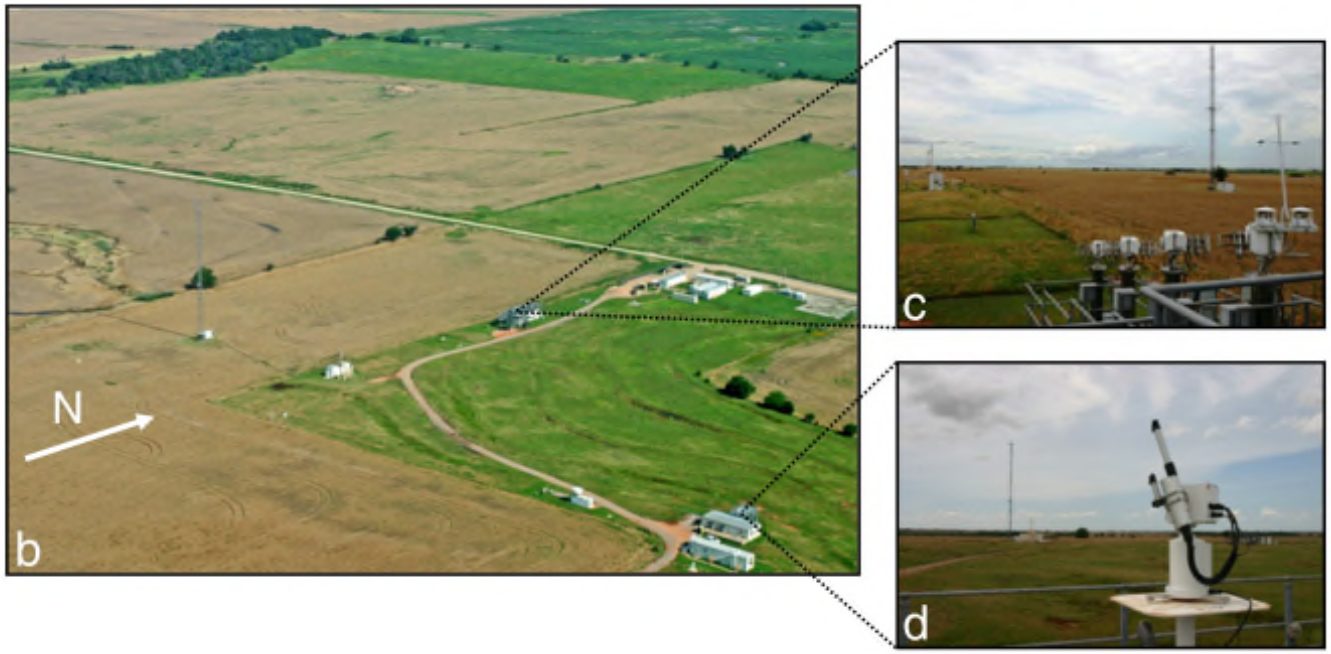


ARM/CART



IKONOS 2.4 m RGB

1.0 km



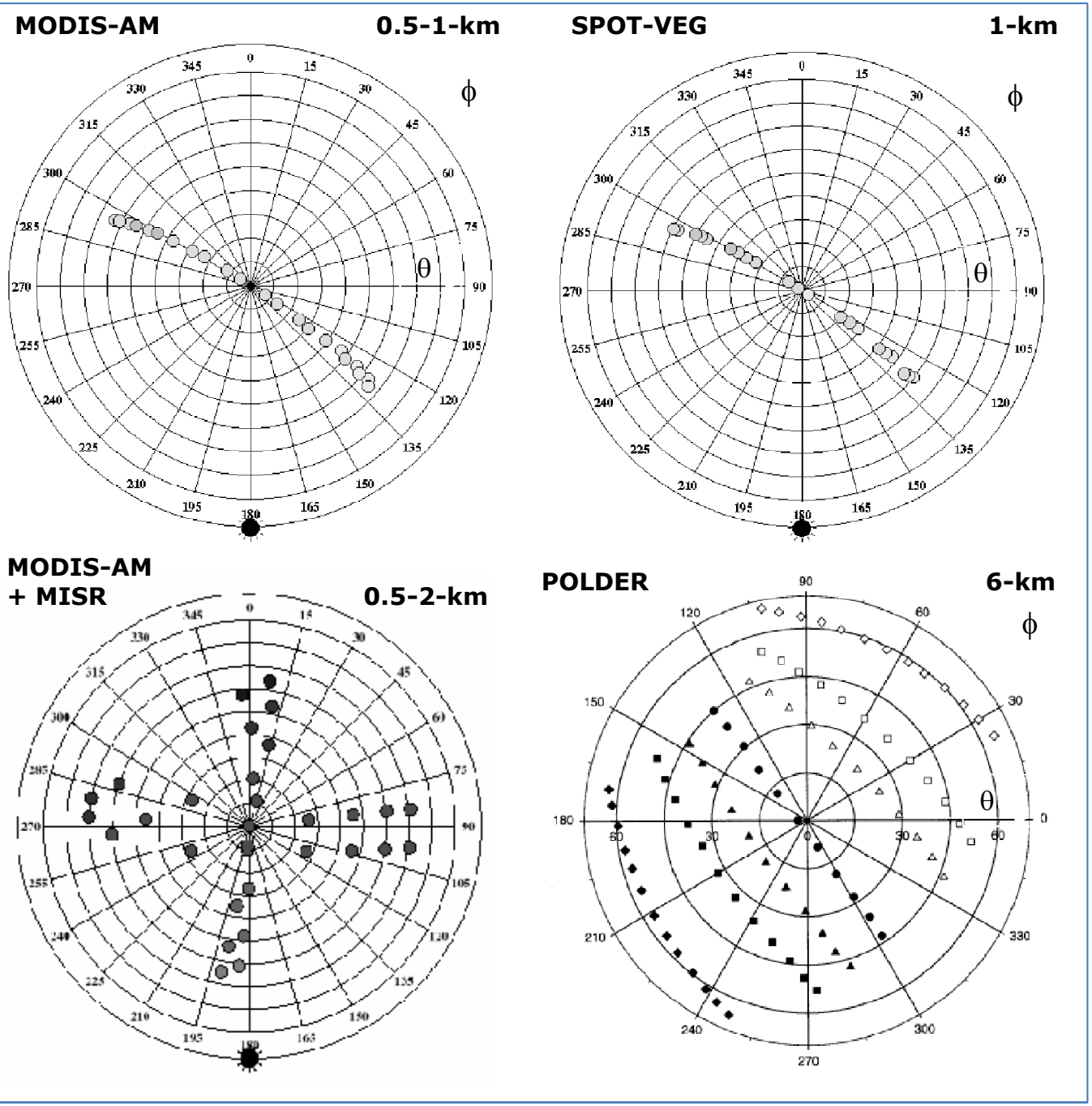
Coincident

Surface BRF and Albedo from Ground, Aircraft, and Satellite.

Best ever

Multi-scale observations of the ARM/CART Site.

BRDF Sampling Constrains – Current Satellite Sensors

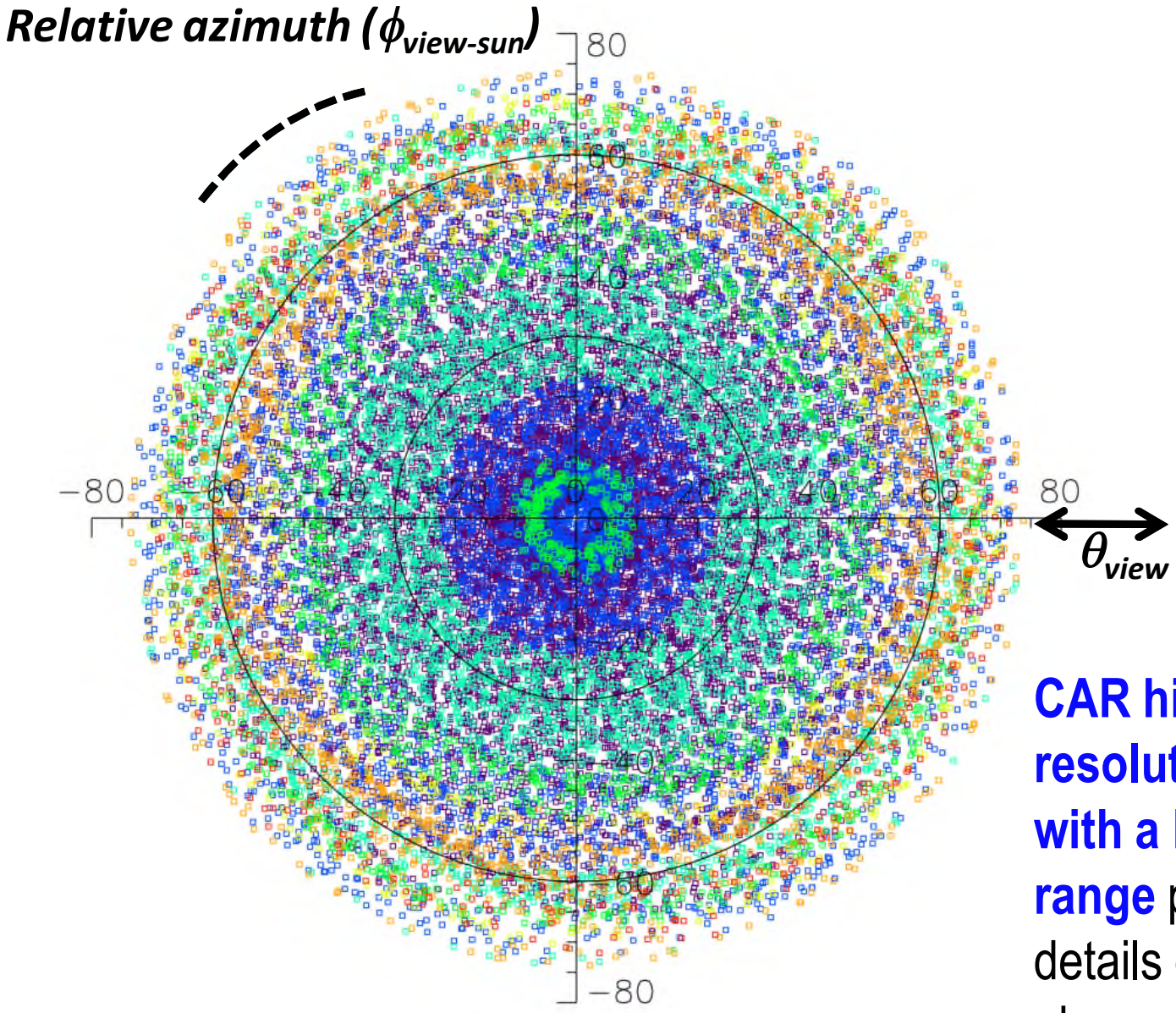


<u>Prediction of BRDF</u>: sampling for MODIS/+MISR, SPOT-VEG, and POLDER (8-days)

Angular constraints are imposed by the satellite orbit and the instrument view geometries.

Román and Strahler, 2007

Cloud Absorption Radiometer: BRDF Sampling



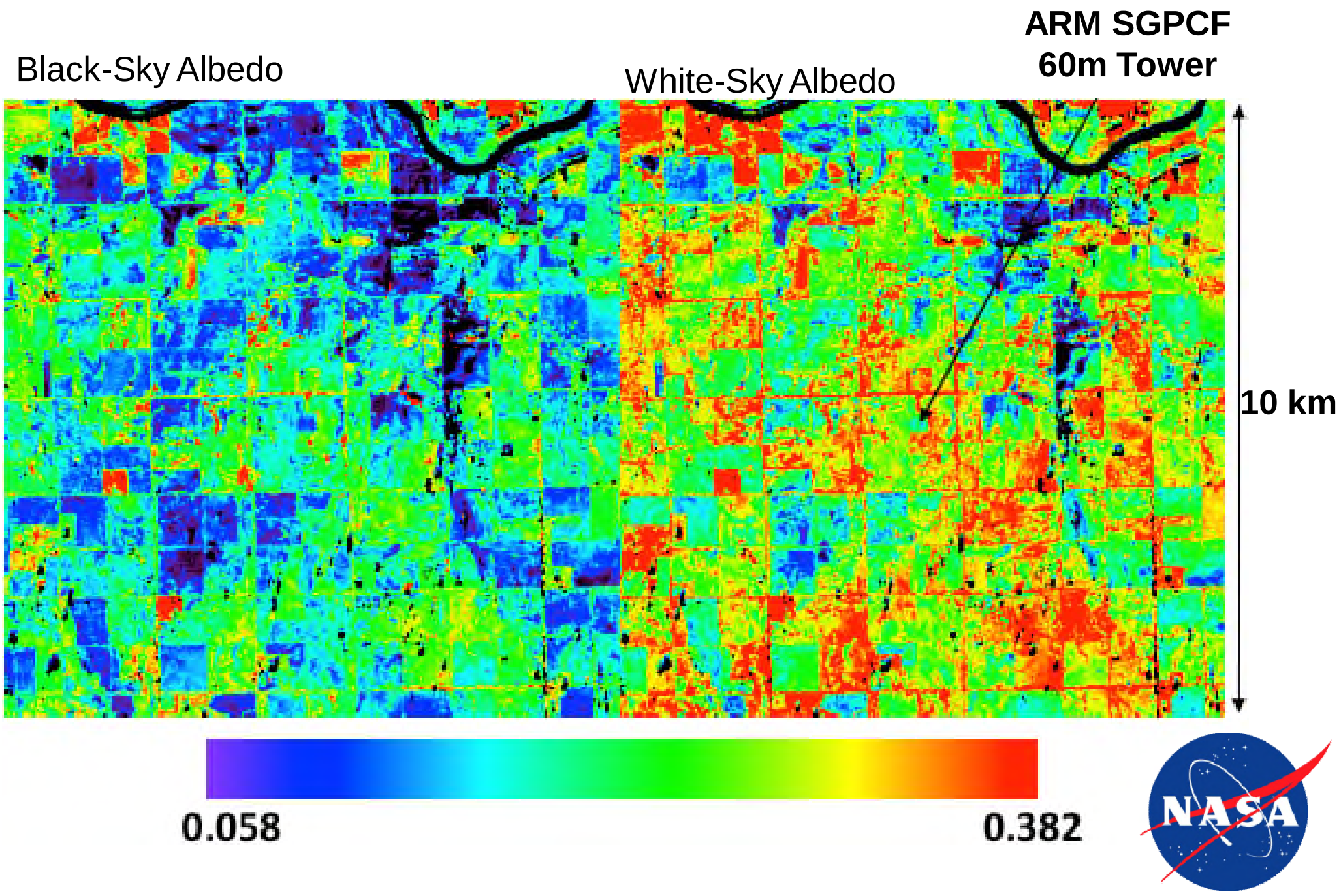
Pixel Size (GIFOV)

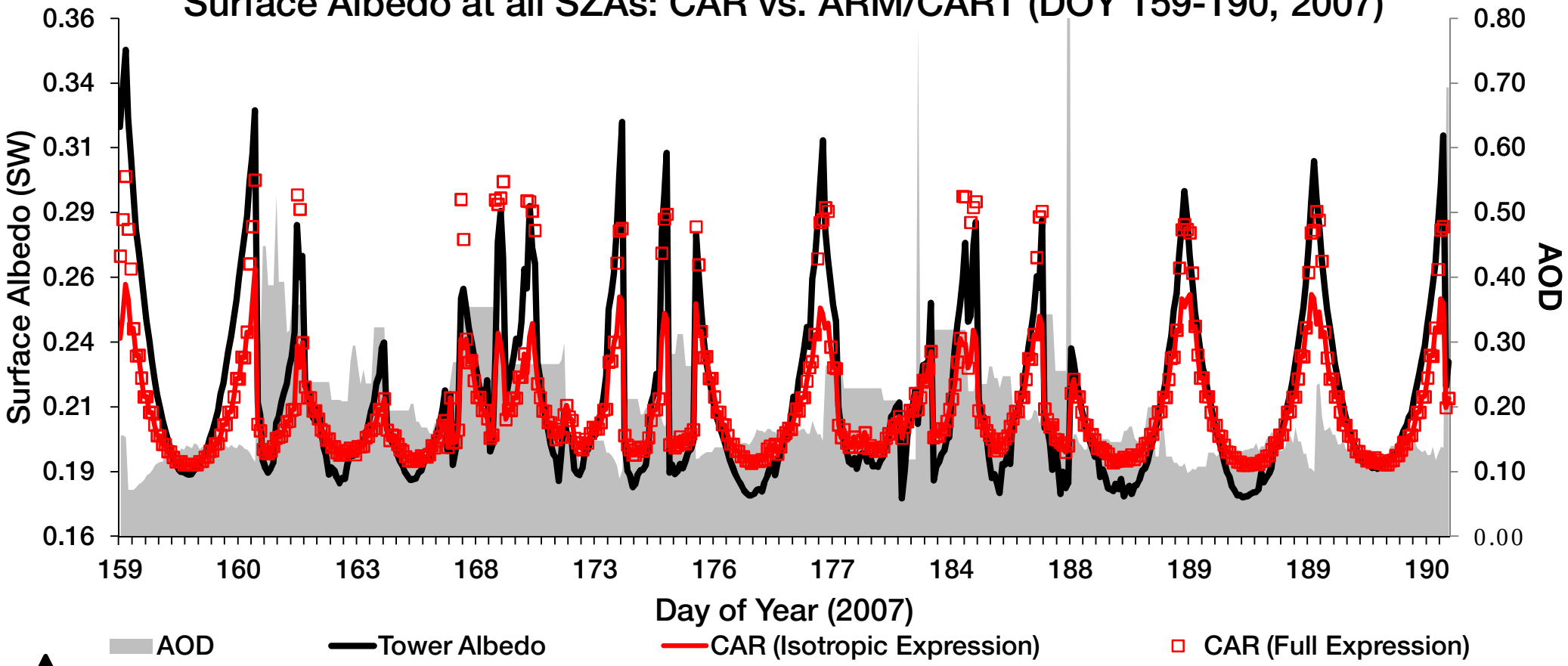
- 5–20m
- 20–40m
- 40–60m
- 60–80m
- 80–100m
- 100–250m
- 250–500m

CAR high angular and spatial resolution (1° IFOV) coupled with a high SNR and dynamic range provides unmatched details of the radiance field above clouds and various surfaces.

Román et al. 2011 - RSE

Intrinsic Albedos (SW: 0.3-5.0μm) derived from CAR

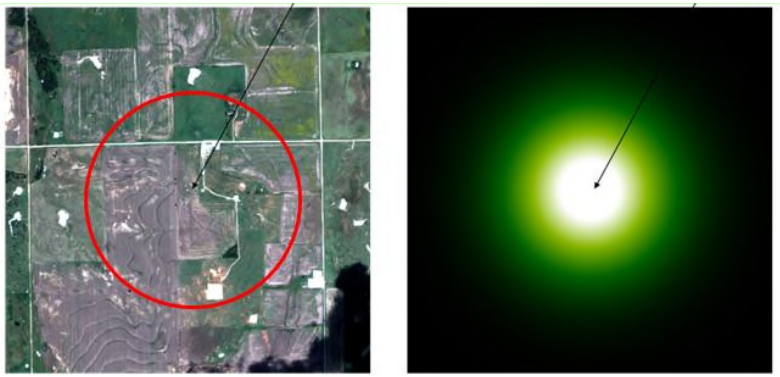




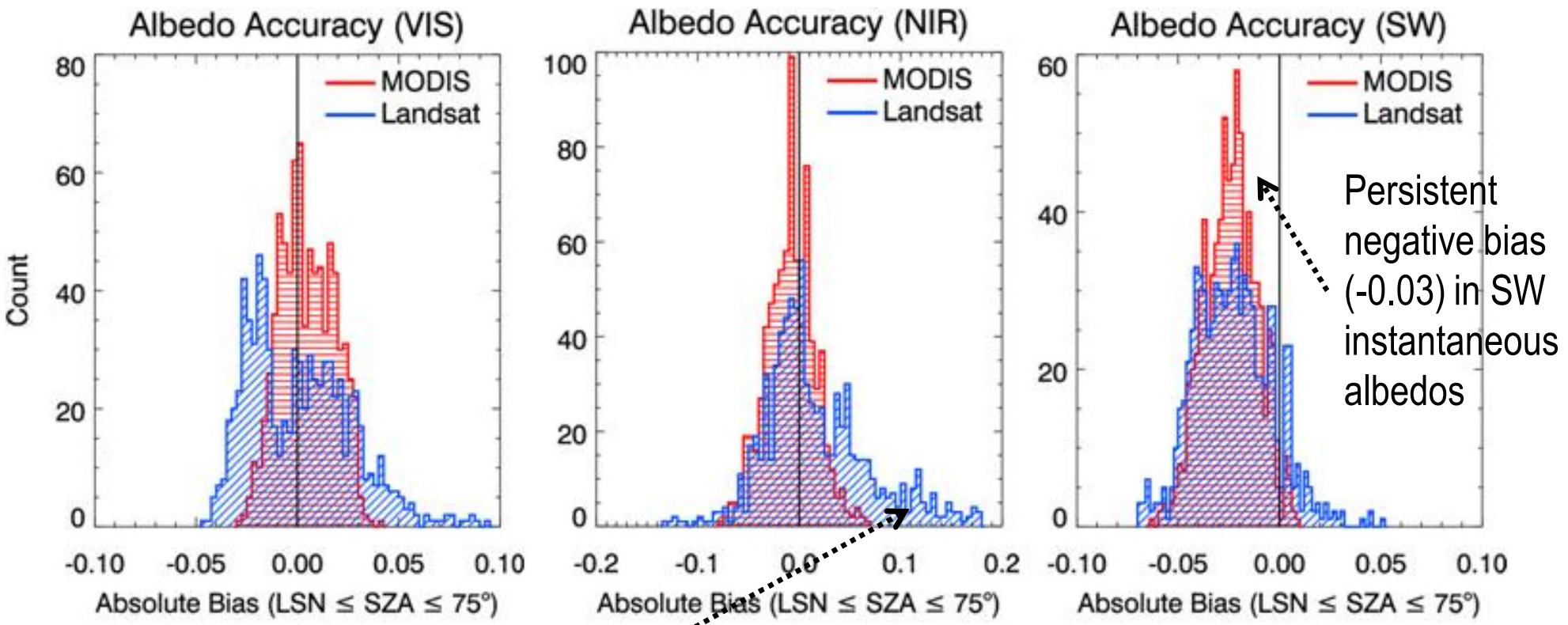
Comparison between instantaneous albedos (30-min intervals) derived from CAR and tower-based measurements acquired at the CART site throughout a 32-day period surrounding CLASIC'07.

	$10^\circ \leq SZA \leq 45^\circ$ (n = 289)	$45^\circ \leq SZA \leq 75^\circ$ (n = 193)
DOY 159-190, 2007	CAR-CRM	CAR-CRM
Accuracy (Bias)	0.0042	-0.0096
Uncertainty (RMSE)	0.0082	0.0184

IKONOS **2D Gaussian**



Román et al., 2012 (submittted)



Landsat NIR albedos show positive biases above the standard accuracy limit of ±0.08.

CLASIC'07 Experiment: Absolute bias and RMSE for MODIS and Landsat instantaneous albedos at UV-Visible, NIR, and SW broadband channels.

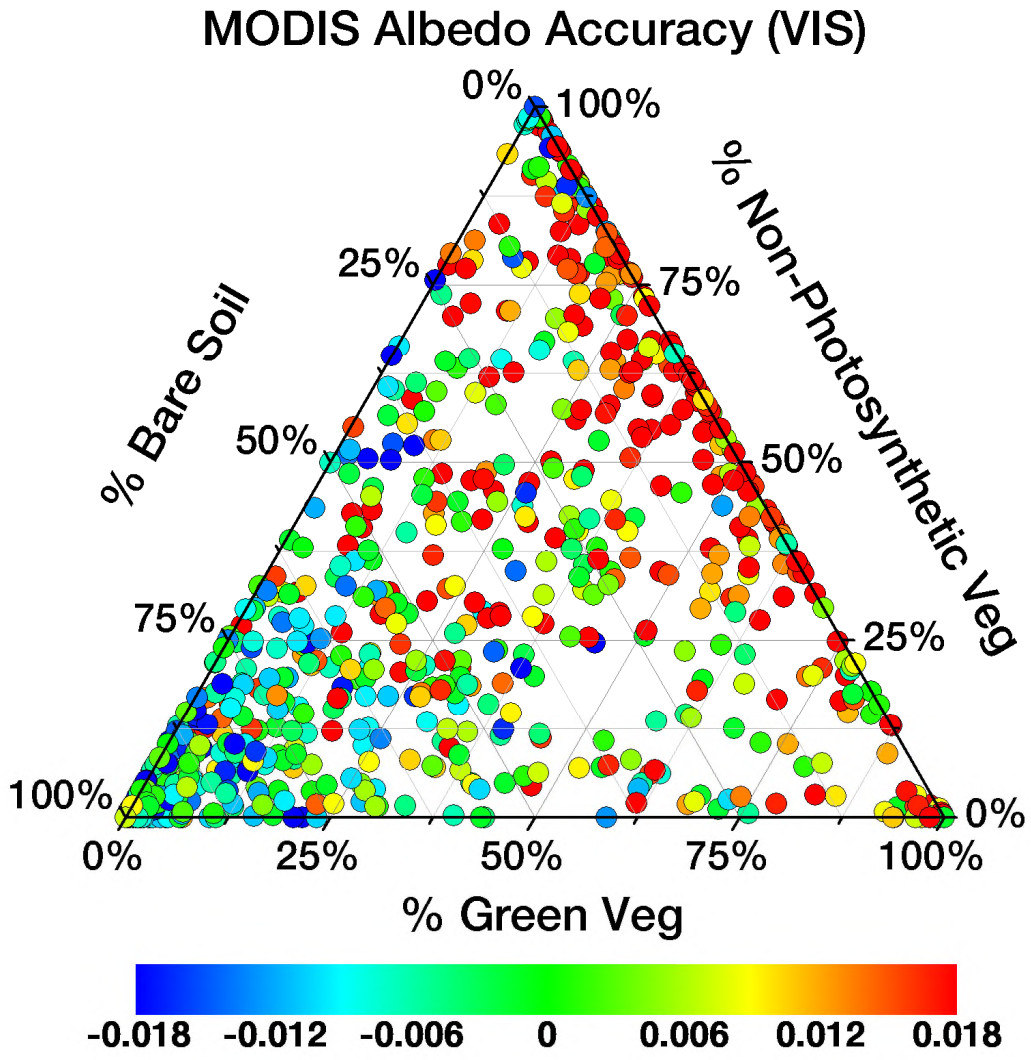
Error propagation terms:

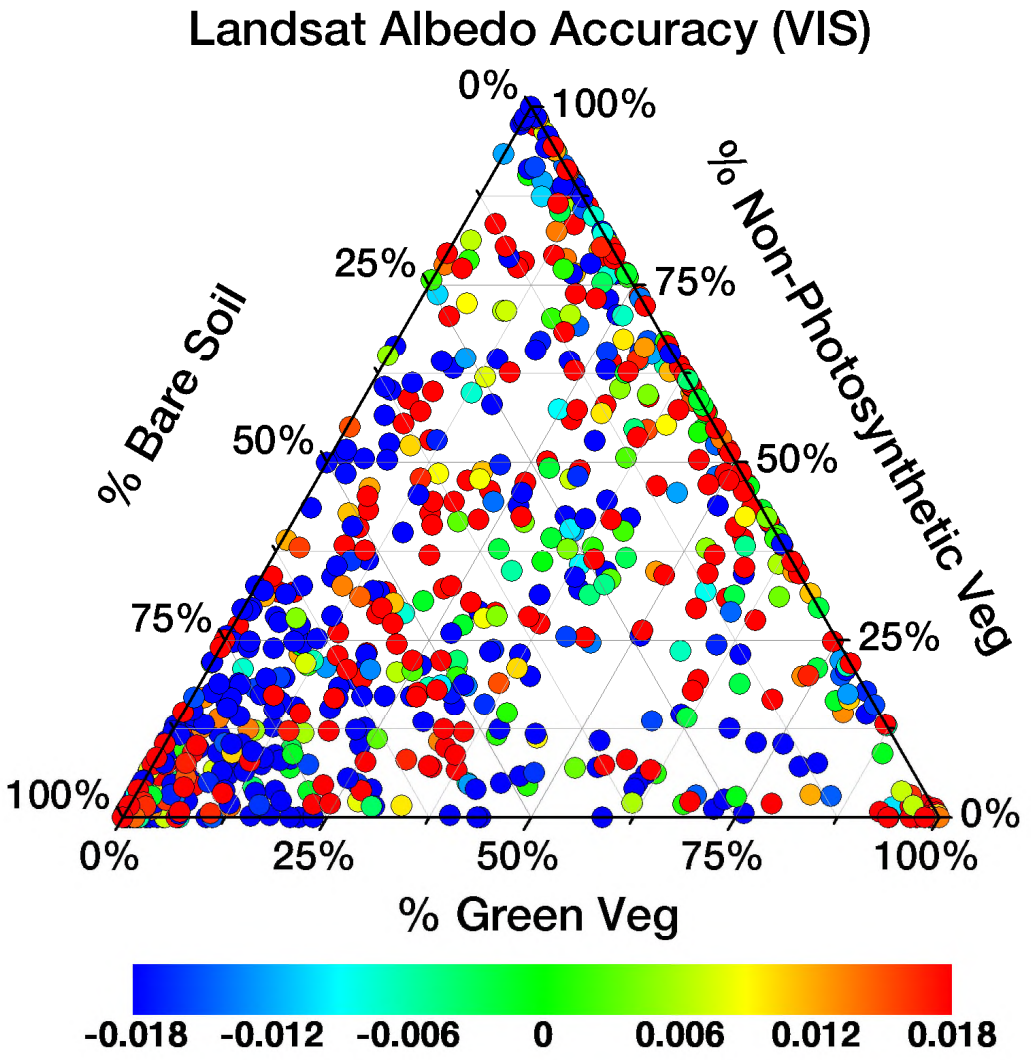
$$RSSE_{MODIS} = \sqrt{Err\left(\hat{\theta}_{tower \rightarrow CAR-CRM}\right)^2 + Err\left(\hat{\theta}_{CAR-CRM \rightarrow MODIS}\right)^2}$$

$$RSSE_{Landsat} = \sqrt{Err\left(\hat{\theta}_{tower \rightarrow CAR-MRM}\right)^2 + Err\left(\hat{\theta}_{CAR-MRM \rightarrow Landsat}\right)^2}$$

Román et al., 2012 (submitted)

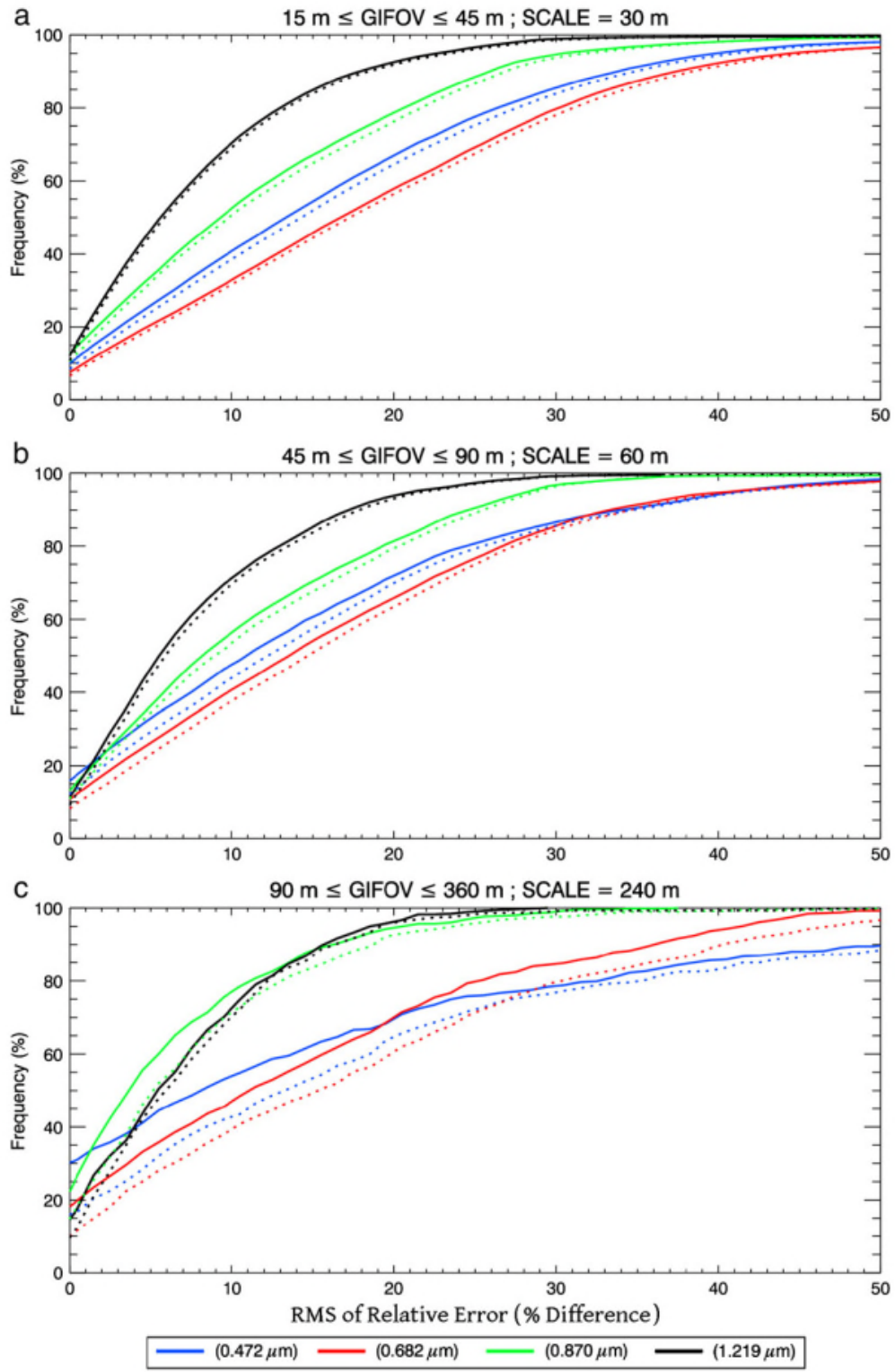
Albedo Accuracy for ‘Mixed’ Landsat and MODIS pixels





Román et al., 2012 (submitted)

M.O. Román et al. / Remote Sensing of Environment 115 (2011) 2184–2203



Sources of Uncertainty:

- During CLASIC'07, the use of dominant archetypal BRDF shapes lead to errors on the order of 6.5% in the retrieved MODIS and Landsat albedos.
- This will particularly affect retrievals where heterogeneous conditions are being lumped into a single land cover class.
- These situations can be addressed by breaking "pure" land cover clusters into multiple sub-clusters representing different anisotropic conditions.

◀ **(Cumulative distribution of differences in Relative RMSE %)**

ΔRMSE% of linear-mixture BRDFs (solid lines)

ΔRMSE% of dominant BRDF (dotted lines)

Summary

- ***(On VIIRS…) Integration is key*** -- i.e., algorithms, instrument characterizations, **calibration/validation**, data processing, etc. A perfect sensor suite would not by itself make for a useful climate data record. Likewise, a state-of-the-art retrieval algorithm does not ensure a useful science data record.
- ***(On the assumptions of scale and spatial heterogeneity)*** Only a ***reference sensor suite*** can overcome the foretold errors due to sub-grid scale and temporal mismatch and the effects of land surface heterogeneity.